APPENDIX C

AN EVALUATION OF THE EFFECTIVENESS OF CURRENT PROCEDURES FOR PROTECTING ANADROMOUS FISH HABITAT ON THE TONGASS NATIONAL FOREST

THE FISH HABITAT ANALYSIS TEAM

September 1994

An Evaluation of the Effectiveness of Current Procedures for Protecting Anadromous Fish Habitat on the Tongass National Forest

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All supporting materials are available by contacting Cal Casipit, USDA Forest Service, Alaska Region (907-586-7918).

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Summary

This report was prepared in response to direction from Congress in the Conference Committee Report to the FY 1994 Appropriations Act for Interior and Related Agencies. The Committee Report asked for a study of the effectiveness of current procedures in protecting fish habitat on the Tongass National Forest, followed by a determination of whether any additional protection is needed.

This report will be incorporated into a broad based report--addressing these and other issues raised by the Committee--that is being produced by the Alaska Regional Office and the Pacific Northwest Research Station, USDA Forest Service. Responsibility for this report was assigned to a study team, called the Fish Habitat Analysis Team (the Team), consisting of fishery biologists and hydrologists from the Forest Service management and research branches, as well as, a fishery biologist from the National Marine Fisheries Service and a habitat biologist from the Alaska Department of Fish and Game. Following direction by the Regional Forester and the Station Director, we conducted studies to evaluate the effectiveness of current procedures and reported our findings. Requirements of the Federal Advisory Committee Act prevented the State representative from participating during the Team's evaluation and recommendation deliberations.

Current direction for protecting fish habitat on the Tongass is to implement the requirements of law as specified by the Tongass Timber Reform Act, the National Forest Management Act, the Clean Water Act, and other laws, as well as the standards and guidelines established by the Forest Service Alaska Region Aquatic Habitat Management Handbook, the Soil and Water Conservation Handbook--Best Management Practices, and the Tongass Land Management Plan. The Tongass Timber Reform Act of 1990 is unique to other forest management legislation in that it directs the Tongass National Forest to protect riparian habitat by establishing a no-commercial-timber-harvest buffer of no less than 100 feet on each side of all anadromous fish streams, and resident-fish-bearing streams that flow directly into anadromous fish streams. The goal for fish habitat management on the Tongass National Forest, as stated in the Forest's land management plan, is to "preserve the biological productivity of every fish stream on the Tongass."

To respond to the study request by Congress, we used a series of interrelated inquiries. Existing published and unpublished reports and data pertaining to forest management effects on fish habitat in Southeast Alaska were collected and analyzed to determine forest management influences on fish habitat in the Pacific Northwest and Southeast Alaska. Established experts in watershed science and fish habitat relations examined a set of managed watersheds and evaluated the effectiveness of current management procedures to protect fish habitat. Three watersheds representing a range of management conditions on the Tongass National Forest Administrative Areas were analyzed by using *A Federal Agency Guide for Pilot Watershed Analysis* (1994).

The assessment of literature yielded 1,542 citations on the relation of land management activities to anadromous fish habitats. Although no studies directly assess Best Management Practices or buffers as applied on the Tongass National Forest, studies in landscapes similar to Southeast Alaska show declines in salmonid habitat capability after timber harvest of more than 25 percent of the watershed. Harvest treatments included some without streamside buffers, some with retained buffers on fish bearing streams but with completely harvested headwaters, and others with a mixture of patch cuts in the riparian area. As a group, these streams incorporated a mix of streamside management that included buffers similar to those currently applied on the Tongass, as well as past Tongass practices. In all of the streams with greater than 25 percent of the watershed harvested, salmonid habitat quality declined.

The results of the expert field review showed that, for current conditions, two watersheds rated as having low risk of a detectable adverse change in fish habitat and watershed condition, five as having moderately low risk, and one as moderate risk. With continuation of timber harvest and roading into the next 30 and 100 years, experts rated risk to fish habitat at either moderate or moderately high. Experts expressed concerns for fish habitat where they observed too narrow buffers on class I and II streams; class III streams that needed buffers; timber harvest activity on unstable slopes; problems with road location, design, and management; and variability in implementing guidance.

The results of the pilot watershed analyses led us to conclude that current fish habitat condition is relatively good and has not been significantly altered by management activities on Game Creek (5 percent timber harvest) and Upper Old Franks Creek (6 percent timber harvest). Kadake Creek (15 percent timber harvest) may be an exception to the conclusion. Watershed analysis, as part of a riparian habitat conservation strategy, was found to provide for more scrutiny of, and emphasis on, riparian-dependent resources and stream processes than do current procedures, especially resource-protection needs adjacent to class III streams.

The conclusion of the Team, based on the information displayed, is that current procedures are not entirely effective in protecting fish habitat. Current procedures have clearly improved the treatment of anadromous fish streams and provided improved protection for valuable stream habitat compared to previous procedures, but they are not completely effective in precluding increased risk to some anadromous fish stocks **over the long term.**

Current procedures were found to be less than adequate in five ways: inventory and classification of fish habitat and streams, and protecting their associated riparian areas and wetlands; timber harvest on steep, unstable slopes; road design, mitigation, maintenance, and closure; problems with certain aspects of forest and timber-sale planning; and institutional concerns.

The team concluded that additional protection for fish habitat is needed to reduce risk to fish habitat quality on the Tongass National Forest. If these measures are implemented in their entirety, we think additional risk to fish habitat associated with timber management activities will be minimized, and the goal of preserving the biological productivity of fish streams on the Tongass will be met, although risk can never be eliminated.

We recommend an ecosystem approach for evaluating and protecting watershed processes and functions at the landscape scale as a precursor to timber sales and other management activities that could significantly influence fish habitat. Parallel with the ecosystem approach, we recommend fully implementing existing Best Management Practices in planning and carrying out activities that could affect aquatic ecosystems. Additional recommendations are made to address institutional, monitoring, and information needs.

Chapter 1. Background

Significant new research information about the status of Pacific salmon and steelhead stocks, current habitat conditions, and habitat requirements in the Pacific Northwest has recently become available. This new information compels the USDA Forest Service to consider immediate and long-term actions to ensure sustainability of anadromous fish habitats on National Forest lands.

In many coastal Pacific areas, naturally reproducing stocks of Pacific salmon, steelhead, and sea-run cutthroat trout are at risk of extinction. Of the more than 400 stocks from California, Idaho, Oregon, and Washington recently evaluated (Nehlsen et al. 1991), 214 were considered to be at "moderate" or "high" risk of extinction or of "special concern," 106 were extinct, and about 120 were considered secure; 134 of the "at risk" stocks are found on National Forests and 109 are found on public lands administered by the Bureau of Land Management.

Although commercial salmon harvests in Southeast Alaska are currently at all-time highs, recent information suggests that some salmon, steelhead, and cutthroat stocks in Alaska may be declining (Halupka et al. 1994). To more accurately characterize the situation in Alaska, researchers began an investigation in 1992 to review the status of stocks of anadromous fish on National Forests in Alaska. The Alaska Chapter of the American Fisheries Society, with others, has undertaken a review of the status of population information accumulated for anadromous fish throughout Alaska. Their findings will be published in the near future.

Reasons for the decline of salmonids differ by species, stock, and geographic area. The depressed status of a stock reflects the interaction of variable conditions, such as oceanic productivity and weather patterns, and a variety of management activities. In general, stock status is influenced by some combination of fish harvest, fish hatchery influences on disease and genetic fitness, and fish habitat conditions.

The Forest Service has an important role to play in managing watersheds and fish habitat in coastal Alaska. The lands administered by the Forest Service contain more than 80% of the freshwater anadromous fish spawning and rearing habitat in Southeast Alaska.

The Nehlsen et al. (1991) report, coupled with the Endangered Species Act listing of the Snake River sockeye salmon and fall chinook salmon as endangered and the Snake River spring/summer chinook salmon as threatened, compelled the Forest Service to develop a proposal for managing Pacific anadromous fish and their habitat (PACFISH). In an effort to address the issue of protecting existing healthy fish stocks and restoring declining fish stocks in Alaska, California, Idaho, Oregon, and Washington, the Forest Service initiated a team effort of managers and researchers in early 1992 to assess fish habitat management and develop a watershed management strategy. The goal of the strategy was to provide habitat conditions that contribute to the recovery and sustained natural reproduction of Pacific anadromous fish stocks on National Forests. During this same time, the Bureau of Land Management began revising its 1988 "Anadromous Fish Habitat on Public Lands" strategic plan. In March 1993, the Forest Service and the Bureau of Land Management announced their commitment to jointly develop a common and comprehensive strategy (PACFISH) for managing Pacific salmon and steelhead habitats and associated watersheds on land administered by the Forest Service and the Bureau of Land Management in the West. The draft Environmental Analysis for PACFISH (USDA/USDI 1994) concluded that applying interim direction to Alaska is not necessary at this time because, in general, the potential for salmon stock extinctions in the near future was small in Alaska compared to the lower 48 states.

The FY 1994 Appropriations Act for Interior and Related Agencies included specific direction that prohibited implementing the PACFISH strategy on the Tongass National Forest. The Act also directed the Forest Service to "proceed with studies and review procedures related to the PACFISH strategy, to assess the effectiveness of current procedures to provide protection for salmon and steelhead habitat, and to determine if any additional protection is needed." The Alaska Region and the Pacific Northwest Station of the Forest Service were asked to complete the requirements of the 1994 Appropriations Act. The Regional Forester and the Station Director jointly approved an assessment plan, following development by the Region and Station leadership teams. Two reports were required: An interim report that was completed on April 1, 1994, and a final report, titled "Anadromous Fish Habitat Assessment on the Tongass National Forest" due October 1, 1994, of which this report is a part.

The Appropriations Act implied two questions:

- Are current procedures for protecting salmon and steelhead habitat effective?
- Is additional protection needed?

These questions address complex issues. Salmon and steelhead populations respond to both natural and human disturbances. Compared to natural disturbances, the effects of human disturbance pose different risks and challenges to salmon stocks. Human disturbances result primarily from fish harvest and land-use activities such as logging. Land-use activities tend to be concentrated in individual watersheds during a shorter period of time and affect a larger total area in the watershed than do most natural disturbances. These human disturbances are cumulative as new watersheds are entered. The fish response to human-caused habitat alteration can continue over decades and therefore cannot easily be evaluated in the 4 year period of post-Reform Act habitat-protection guidelines covered by this study. Measuring the effectiveness of current procedures is also difficult to undertake outside of the context of past practices because the past practices influence present risk (Tilman et al. 1994).

To answer the questions, we needed to understand the current direction for protecting fish habitat. Direction for land management on the Tongass National Forest results from many sources of law, regulation, and policy, all of which are integrated into the land management plan. The Tongass Land Management Plan, developed in 1979, was the first Forest Plan to be completed after the enactment of the National Forest Management Act in 1976. The Plan was significantly amended in 1986 and again in 1991 to respond to the requirements of the Tongass Timber Reform Act. Among the requirements is a 100-foot minimum, no-commercial-timber-harvest buffer along salmon streams (class I) and resident fish bearing streams that flow directly into anadromous fish streams (class II).

The Tongass Plan has been under revision since 1989. A Draft Plan was released for review by the public in early 1990, just before the Tongass Reform Act was passed. Changes were required by the Reform Act, and the Draft Plan was supplemented late in 1991. Since 1991, several issues (including fish habitat) have surfaced, and the Plan Revision has not been completed. An additional supplement to the draft Environmental Impact Statement is likely to be needed, and a final plan is anticipated in late 1995.

The 1979 Tongass Plan states that the goal for fish resources is to "preserve the biological productivity of every fish stream on the Tongass." We evaluated the effectiveness of current procedures in terms of attaining this current management goal. Several handbooks have been developed by the Forest Service to achieve this goal, including the Aquatic Habitat Management Handbook (1986) and the Soil and Water Conservation Handbook--Best Management Practices (1990, 1991, and the most recent version dated June 1993). The Channel Type User Guide (Paustian 1992) was developed to provide a classification scheme for streams and to guide understanding of the potential effects of management activities on fish habitat.

The anticipated Tongass Plan Revision includes more-detailed guidelines for managing fish habitat than were included in the original plan and the Aquatic Habitat Management Handbook. The Plan Revision would establish a boundary for riparian management areas based on three factors: a minimum distance from all streams, the area encompassed by riparian soils along streams, and the area with soils of very high hazard for mass movement that could encroach on either the riparian soils or the minimum distance area. For each combination of channel type (actually for groupings of channel types, called "process groups") and stream class, specific management guidelines are established for the riparian management area by the proposed Plan.

Current policy on the Tongass is to implement the requirements of law (the Tongass Timber Reform Act, regulations of the National Forest Management Act, Clean Water Act, and other laws not described here), as well as the standards and guidelines established by the Aquatic Habitat Management Handbook and Soil and Water Conservation Handbook--Best Management Practices. Most current projects also have been incorporating the guidelines proposed by the Forest Plan Revision for managing by channel type and stream class, although using them has been optional.

The State of Alaska passed the Alaska Forest Resources and Practices Act in 1990, requiring that minimum buffers be maintained along salmon streams on all public and private lands in Alaska. On federally managed public lands, the state Act specifies a minimum 100-foot no-harvest buffer.

Our approach in responding to the two questions was to review literature and existing published and unpublished reports and data from the Alaska Region of the Forest Service and elsewhere; to arrange a field review of a set of managed watersheds by an expert group of fisheries and watershed scientists; and to analyze managed watersheds from three locations on the Tongass. We used our professional knowledge and experience to evaluate, interpret, and integrate these separate methods to provide answers to the questions. These actions were approved by the Alaska Region and Pacific Northwest Station leadership.

We interpreted "current procedures" as those that have been in use since the passage of the Tongass Timber Reform Act in late 1990. Therefore, we attempted to look at only procedures, and the resultant practices implemented on-the-ground, from 1991-94. We understand that practices and procedures in 1994 may be different from those used in 1991; however, we had to have a sufficiently long period of on-the-ground implementation of procedures to evaluate as "current."

This report is intended both for Forest Service leadership and for Congress. For the Forest Service it is a review, interpretation, and evaluation of available information about current measures and their success, as well as an estimate of what more may be needed. For Congress, it is supporting information for the study requirement posed as part of the FY 1994 Appropriations Act.

Chapter 2. Biogeographic Setting

GEOGRAPHIC SETTING

Southeast Alaska is a part of the North American Coast Range that extends from Mexico to the Alaska Peninsula. This range is a broad belt of interconnected mountains produced by several periods of folding, faulting, and intrusion that have resulted in complex geology and rough, steep terrain. More recently (geologically speaking), the primary factor in developing the present landforms in Southeast Alaska has been glaciation. The climate, landforms, and resources of Southeast Alaska are similar to coastal British Columbia, Washington, and Oregon.

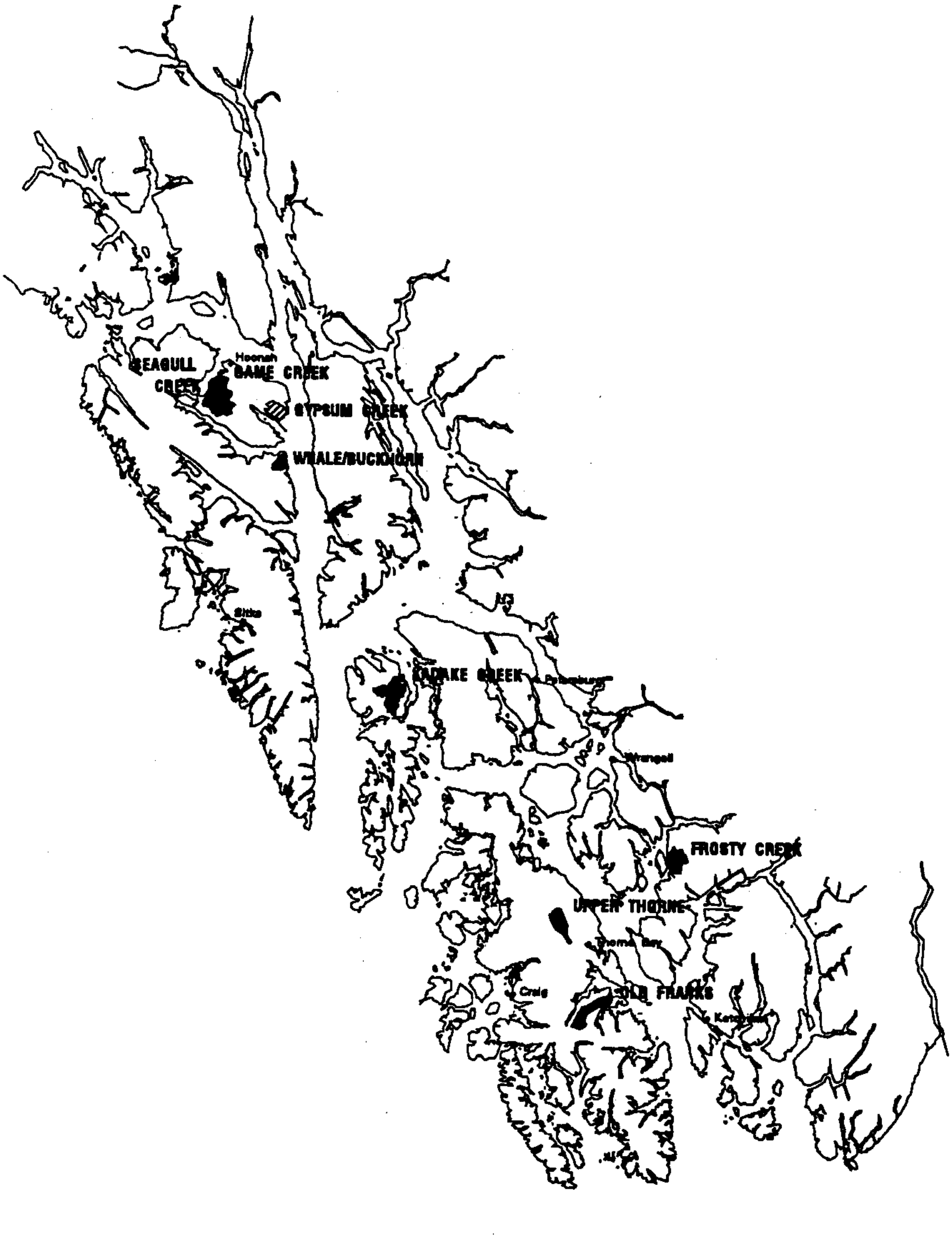
About one million years ago, all but the highest mountain peaks in Southeast Alaska were covered by ice. The great erosional powers of these vast expanses of ice molded and shaped the landscape as the glaciers moved downhill under their own weight, carving the bedrock below them. When the ice receded and uncovered the land, a network of islands dissected by numerous streams, U-shaped valleys, and fiords was revealed. Many areas of Southeast Alaska are still undergoing glacial rebound, a rise in the surface elevation after the unweighting of the land as the glaciers recede.

Southeast Alaska consists of six large islands: Prince of Wales, Chichagof, Admiralty, Baranof, Revillagigedo, and Kupreanof; numerous smaller islands; and a strip of mainland along continental North America. The islands, known as the Alexander Archipelago, and the mainland are between 54.5 and 60.5° N latitude and 141 and 130° W longitude (fig. 1). The general orientation of the major land mass is northwest to southeast, with a width of 120 miles and a length of 525 miles (Harris et al. 1974). Nearly 11,000 miles of shoreline extend along the islands and mainland. Southeast Alaska is relatively undeveloped and sparsely populated with a naturally fragmented landscape.

The topography of Southeast Alaska is dominated by mountains. The eastern boundary mountains on the mainland are extensions of the Cascade Range in Washington and the Coast Range of British Columbia. Peak elevations along these mountains are between 6,000 and 10,000 feet. Elevations of forested areas extend up to about 3,000 feet in the southern sections of the forest, and up to 2,500 feet farther north. The mountains and their associated icefields form an effective barrier to many organisms common to continental and interior North America, and strongly affect weather patterns. The Coast mountains are dissected by several major river systems; among them are--north to south--the Alsek River, the Taku River, and the Stikine River. The mountains on the islands are an extension of the Vancouver system and are lower in elevation than those on the mainland. The mountain and glacial-valley topography of the islands forms a series of small watersheds throughout the Alexander Archipelago. The streams in these valleys, typically less than 15 miles long, are fed by low-order (class 1-3) streams (Strahler 1957) ranging from steep head-wall cascades with gradients of >30% to low-gradient meandering channels of <1%.

Southeast Alaska has a maritime climate, resulting from the moderating influence of the Pacific Ocean. The two most dominant features of the weather in Southeast Alaska are precipitation--primarily rain--and wind. The configuration of the coastline, the warm ocean currents, and the high coastal mountains provide the factors necessary to produce abundant rainfall. The annual precipitation of Southeast Alaska averages more than 100 inches, and is generally highest in the south. At higher elevations, more than 300 inches of snow may fall annually, perpetuating icefields and glaciers. Storms and moderate to heavy precipitation occur year round, but peak rainfall is from September through November. These storms are often accompanied by high winds that are amplified by mountainous terrain and steep valleys.

Figure 1--The Alexander Archipelago and Southeast Alaska



The ocean provides a cooling influence in summer, and temperatures in winter are warmer than would be expected for these latitudes. Mean monthly temperatures range from the mid-40's to the mid-60's (°F) in summer, and from the high teens to the lower 40's (°F) in winter. During the warmer months, temperatures are highest inland and lowest along the coasts, but in the colder months, the reverse is true.

Both glacial and non-glacial river and stream systems occur throughout Southeast Alaska. Most of the glacial rivers are on the mainland and originate in the glaciers and snowfields of the Coast Range. Some of the largest of the mainland rivers originate from glaciers in Canada.

In addition to glaciation, natural geologic processes include soil mass movements (landslides and debris torrents), streams cutting new channels, and streambed or bank erosion. These geologic processes are the main natural agents modifying the land. The generally steep terrain and large amounts of rainfall make the land sensitive to natural sediment production; at the same time, the abundant rainfall allows vegetation to grow rapidly on exposed soils. Extreme winds, associated with intense storms in the Gulf of Alaska, are the cause of frequent natural disturbance that results in openings (windthrow of trees) in forested areas, and the expansion of openings created by human activities such as timber harvest. Windthrow-induced natural openings can range from under an acre to hundreds of acres.

Streamflow regimes generally follow rainfall pattern with peak flows from September through November. From April through June, peak flows are primarily from snowmelt. Occasional large peak flows can occur November through June as a result of rainfall-on-snow events. Glacial streams and rivers typically show high flows in midsummer from snowmelt runoff. Most streams influenced by forest management practices are fed by precipitation runoff that reflects the fall peak flow pattern and spring snowmelt.

The combination of highly saturated soils, steep topography, and high-intensity rainfall contributes to rapidly increasing flows that can vary by an order of magnitude over a few days (James 1956, Schmiege et al. 1974). Seasonal floods and high-intensity flows play an important part in stream habitat and affect stream-channel morphology, riparian zones, and distribution of rearing salmonids.

Sitka spruce and western hemlock are the predominant tree species in old-growth forest riparian zones. Red alder predominate in disturbed areas such as gravel bars, landslide tracks, and flood plains. The large old-growth conifers are key elements of the structure and function of most stream channels and riparian zones of Southeast Alaska. The importance and function of large wood in the stream ecology of the Pacific Northwest, Alaska, and other river systems of the world are reviewed and discussed by numerous authors, including Bisson et al. (1987) and Bryant and Sedell (in press). The role of large wood in streams changes as a function of stream size. Small headwater streams typically have higher accumulations of large wood spaced at random intervals in the channel (Bisson et al. 1987). Debris in small streams serves to trap sediment, provides a long-term nutrient source, and serves as colonizing substrate for invertebrates. Large wood in headwater streams is typically not transported long distances, except during debris torrents (Swanson et al. 1982). In larger streams, wood is typically spaced in large clumps that are farther apart (Swanson et al. 1982). Large wood in larger streams provides an important link to the riparian zone and serves a similar role to that in smaller streams, as well as becoming a dominant fish-habitat-forming feature in channels (Bryant 1985, Bisson et al. 1987).

Distribution of large wood in streams tends to be patchy, producing irregular accumulations of gravel patches of varying size distribution. Woody debris accumulations increase habitat heterogeneity and decrease the size of gravel bars and the rate of sediment movement into low-gradient deposition zones. In undisturbed stream systems of Southeast Alaska, accumulations of large wood can range from 62 to more than 550 pieces greater than 3 feet in diameter per mile of stream in low- to medium-gradient channel types. Heede (1972) describes a stair-step stream profile formed by wood debris in small mountain streams; the same process occurs in moderate-gradient, third order streams with large conifers (>30 ft long) that fully span the channel.

In Southeast Alaska, large wood often remains in the stream for more than 50 years (Bryant 1980, Murphy et al. 1989). In old-growth forest streams, wood is replaced on an erratic, but continual cycle, resulting in a dynamic equilibrium. Where many pieces of large wood pile up along a stream course, gravel bars tend to be small, and infrequent failures release small amounts of gravel that are captured a short distance down the stream by another accumulation of large wood. Removal of the source of large wood results in infrequent accumulations and the formation of large gravel bars and, in low-gradient streams, a long, uniformly shallow channel morphology (Smith et al. 1992).

The nature of substrate in a stream channel is largely determined by the parent geological material. Extensive glacial deposits in most of Southeast Alaska influence many streams that have extensive deposits of glacial tills throughout the watersheds. One example is given by Swanston (1969) for the Maybeso valley with several identifiable glacial deposits, all of which consisted of boulders, cobbles, and pebbles. Weathering of rock further contributes to the substrate composition of these glacially sculpted streams. The ultimate delivery mechanism to the stream is gravity, through erosion and landslides. On steep slopes, streams are highly erosional (Paustian 1992) and an important mechanism for sediment transport. Mass failures and landslides in undisturbed systems are important sources of sediment to streams (Swanston 1976, Swanson et al. 1987). Small mass failures associated with timber harvest are more frequent, but the frequency of large mass failures does not change (Swanston 1976, Swanston and Marion 1991).

Size composition of substrate and its influence on aquatic productivity and spawning success is well studied (Everest et al. 1987). As a general statement, the size composition of the gravel substrate in these glacially formed stream systems provides productive habitat for invertebrates and salmonid embryo survival. The topography and hydrology of these systems influence substrate distribution. The short distance between the source and deposition zone and seasonal high-flow events facilitate the moving and redistribution of coarse sediment and soil material throughout the watershed.

These same features--high gradient and water velocity--also move bedload through an unobstructed channel rapidly, sometimes resulting in degradation and streambed downcutting. Channel obstructions capture and stabilize bedload. The effects of large wood in sediment routing is documented in streams throughout the Pacific Northwest (Lisle 1986, MacDonald and Keller 1987, Smith 1990). In a small tributary stream, Smith et al. (1993) reported a four-fold increase in bedload movement after removal of large wood from the channels after fall storms.

The U-shaped valleys of the glacially sculpted topography of Southeast Alaska receive sediment deposits from the steep slopes, glacial deposits in the valley, and alluvial debris cones. These sediments interact with large wood and stream-flow to form highly productive habitat for anadromous salmonids. The streams that run through this terrain tend to form unconstrained channels with wide flood plains (Paustian 1992). The well-drained alluvial flood plains are productive forest sites that support large conifers (Harris and Farr 1974). Large wood along and in these streams serves to stabilize substrate movement, but also functions to connect the main stream to the flood plain, create meanders and side-channels, and contribute to habitat heterogeneity (Bisson et al. 1987).

Examples of habitats found in the alluvial flood plains include low-gradient meandering tributary streams, side-channels adjacent to 4th- and 5th-order main streams, and off-channel ponds, including beaver ponds. These habitats found on alluvial flood plains are often the most productive areas for anadromous salmonids (Peterson 1982, Sedell et al. 1984, Bryant 1985, Wright and Bryant in press). The flood plains extend over a broad area away from the main channel and may be disconnected from the channel during parts of the season, particularly in summer when stream flows in Southeast Alaska tend to be low. The structure of the habitat is maintained by the surrounding forest, but the connection to the main channel is often maintained by seasonal flooding.

Seasonal floods move sediment--organic and inorganic--into the riparian zone and open pathways for fish to move into previously inaccessible habitats. Beaver dams that appear to be barriers are overflowed or bypassed by rising water, side channels are recharged and reconnected to the main channel, and off-channel pools are connected. During fall floods, juvenile salmonids--particularly coho salmon--follow flood waters into these habitats and remain over the winter. Spring floods provide passage out for smolt. Coho salmon parr may remain over the summer and emigrate the following spring. Evidence from studies in Southeast Alaska beaver ponds suggest that coho parr rearing in ponds are larger than those rearing in adjacent stream sections (Bryant 1985, Sampson 1994). Overwinter survival also appears to be greater in these habitats than in main stream channels (Bryant 1985).

LIFE HISTORY OF SALMONIDS OF SOUTHEAST ALASKA

Salmonids are the dominant fish species of Southeast Alaska. These species contain genetic stocks of fish that are of great economic and cultural importance in Southeast Alaska (table 1). These stocks are important in maintaining the populations of salmon species in Southeast Alaska. Current information suggests that some salmon stocks may be differentiated at the watershed scale (Halupka 1994). Stocks are recognized as equivalent to species under the Endangered Species Act (Waples 1991). All salmonids are or can be anadromous (McDowall 1988); that is, they can exploit both marine and freshwater habitats. Their ability to use the marine habitat allows them access to freshwater habitats on the islands and the isolated mainland of Southeast Alaska.

Table 1--Salmonid species in Southeast Alaska and type of fishery

Scientific name	Common name	Fishery
Oncorhynchus clarkii	Cutthroat trout	Subsistence/sport
Oncorhynchus gorbuscha	Pink salmon	Subsistence/commercial/sport
Oncorhynchus keta	Chum salmon	Subsistence/commercial/sport
Oncorhynchus kisutch	Coho salmon	Subsistence/commercial/sport
Oncorhynchus mykiss	Rainbow trout/steelhead	Subsistence/sport
Oncorhynchus nerka	Sockeye salmon	Subsistence/commercial
Oncorhynchus tshawytscha	Chinook salmon	Subsistence/commercial/sport
Salvelinus malma	Dolly Varden char	Subsistence/sport
Salvelinus fontinalis	Brook trout (introduced)	Sport

Historically, Alaska salmon harvests have fluctuated over a 20- to 30-year cycle. Salmon harvest has peaked in 1915, 1935, 1968, and 1991. Lows have occurred in 1921, 1960, and 1975. Since 1985, favorable oceanic habitat conditions have contributed to excellent salmon survival and growth (Beamish and Bouillon 1993). For example, survival from smolts to returning adults averages 5% over the long term. In recent years, the survival of coho salmon has averaged 30% in some areas. Although salmon populations have been increasing, populations of steelhead and anadromous cutthroat trout have generally declined in recent years (Alaska Department of Fish and Game, Sportfish Division 1994).

Great diversity exists both in the use of freshwater habitats and the amount of time spent in freshwater and the ocean by different species of salmon (Randall et al. 1987, McDowall 1988). Pink salmon spawn in freshwater or intertidal gravel, and the fry immediately migrate to estuaries and marine waters; chinook salmon may spawn more than 1,600 miles upstream in large rivers, with juveniles remaining in freshwater for 1 to 4 years before migrating (Healey 1991, Heard 1991). Freshwater habitats used by juvenile salmonids may range from small streams for coho salmon to lakes for sockeye salmon. Anadromous salmonids may also become landlocked and spend their entire lives in freshwater.

Development of anadromy in this large group of fish suggests an advantage in survival that offsets the risks encountered by extensive migration. In northern latitudes, marine productivity is higher than in freshwater (Gross 1987); species able to exploit the marine environment grow faster than their resident counterparts. Freshwater habitats offer more-favorable conditions for egg and embryo survival and better survival for small, young fish than does the marine environment. Marine survival of pink salmon fry that migrate to sea range from 1.7 to 4.7% (Heard 1991); marine survival is much higher (from 5-20%) for coho and sockeye salmon smolt reared in freshwater (Holtby et al. 1990, Henderson et al. 1991).

The dependence of anadromous salmonids on freshwater habitat leaves them highly vulnerable to human actions that degrade habitat, and the degree of vulnerability may be related to how long the species spends in freshwater (Gross 1987). Pink and chum salmon use freshwater habitat for spawning and incubation only. Coho, chinook, and sockeye salmon use freshwater for spawning and rearing, which increases the risk to those species from detrimental land management practices.

Anadromous fish have existed for centuries in Southeast Alaska with episodic natural disturbances such as floods, large-scale windthrow, and landslides. These disturbances are generally short-term, infrequent, and primarily limited to small areas within watersheds. Although disturbances may affect anadromous fish locally, high-quality refuges near disturbed areas ensure that source populations can re-distribute fish to them as habitat recovers (Sedell et al. 1990, Reeves et al. 1993). Populations subjected to disturbance are generally resilient and recover in time. When human-caused disturbances are added to natural disturbances, they affect both the frequency and magnitude of the effects on anadromous fish (Reeves et al. 1993, Reid 1993). Managed forests typically have harvest units and roads throughout a watershed. Harvest units are generally managed to grow and harvest trees every 100 years on suitable soils. In addition to the final harvest, timber stands may be thinned twice before final harvest. When combined with natural disturbance, the effects from human-caused disturbance may be greater and may also affect an entire watershed. Frequent disturbances may limit habitat recovery, reduce the availability of key refuges in streams, and limit the ability of local populations to recover (Sedell et al. 1990). This problem is particularly critical to small populations or stocks where minor changes may pose a risk of extinction (Rieman and McIntyre 1993). These small populations and stocks likely occur in many small island streams in Southeast Alaska.

Effects of Land Management Activities

Spawning Habitat and Embryo Incubation

Land management activities in the riparian zone and the watershed can affect fish reproduction and survival by changing gravel composition, spawning bed stability, and temperature regimes during incubation. The effects of increased sediment loads in streams are reviewed by Everest et al. (1987), and the detrimental effects of increased fine sediment on survival of both pink and chum embryos is well documented (Cooper 1965, McNeil 1969, Phillips 1971). Increased fine sediment decreases intragravel water flow, which decreases oxygen delivery and metabolic waste removal (McNeil 1969). Heavy siltation after spawning can form a physical barrier to emergence by compacting the gravel (Phillips 1971). Few conclusive results are available on effects of forest management, their relation to sediment production, and the ultimate effects on salmon and steelhead in Southeast Alaska (Sheridan et al. 1984).

Flows that scour stream beds or deposit excessive gravel on top of redds increase mortality of developing eggs. Scouring flows during high-intensity storm events are typically after egg deposition in the fall in Southeast Alaska. Mortality is density independent; small runs (or weak stocks) are affected at the same rates as strong runs. Activities that increase channel instability, such as removing large wood and its sources, increase the effects of natural events.

Temperature regimes affect incubation time of salmonid embryos (Tang et al. 1987), and changes in canopy cover change stream temperature (Brown 1970). The effects of decreased temperature during the winter are poorly documented, but extremes may freeze incubating embryos. Of greater significance is the potential of temperature to change when the fry emerge. Human-induced changes to temperature regimes alter incubation times and subsequent emergence times, changing the time fry arrive at the marine environment by weeks or months. The fry could enter the marine ecosystem either before or after optimum food availability.

Pre-spawner mortality occurs in both undisturbed and harvested watersheds and is attributed to low oxygen caused by high spawner densities, low flows, and high water temperature (Murphy et al. 1985, Martin 1993). The amount of oxygen that can be dissolved in water decreases with increasing temperature. Land management practices that tend to increase temperature or reduce summer flows increase the probability of depressed oxygen during peak spawner returns.

Rearing Habitat

Critical habitat requirements of rearing anadromous salmonids are access to habitat, both spawning and rearing; seasonal stability of habitats; and complexity in habitat units, watersheds, and landscapes. Degradation of any of these three requirements, either through poorly designed road crossings or simplification of watersheds through loss of large wood, is detrimental to survival of rearing fish. In Southeast Alaska, the effect will be greater on coho than on either chinook or sockeye salmon. Large wood is a key feature for rearing habitat of juvenile salmonids throughout forested streams in the Pacific Northwest and Southeast Alaska (Bisson et al. 1987).

Rearing habitat for juvenile salmonids often extends well beyond the main channel into smaller channels within the riparian zone. These habitats are critical for overwinter survival, but they are often not readily apparent during other seasons. Most of these habitats, side-channels, intermittent streams, and perennial pools depend on an intact forest system. Large trees in these habitats provide streambank stability, shade, and large wood that gives structure and complexity to the flood plain.

ATTRIBUTES OF HEALTHY AQUATIC SYSTEMS AND KEY FISH HABITAT OBJECTIVES

Healthy aquatic ecosystems provide habitat of sufficient quality and quantity to produce naturally self-sustaining populations of resident and anadromous salmonids. These populations reflect the historical composition and distribution of salmonids found within those systems. The goal for aquatic systems should be to provide for resilience and stability in fish populations. We recognize that populations are under constant stress from both human activities and other natural disturbances. The key to maintaining populations in the face of these disturbances lies in having sufficient healthy populations of anadromous and resident fish and high-quality habitat available as refugia for their survival (Sedell et al. 1990).

Indicators of healthy aquatic systems should integrate key biological, chemical, and physical characteristics into a representative set of variables that are used to diagnose the relative "health" of the system (Rapport 1992). These indicators are surrogates for the variety of conditions that reflect system health. To determine human health, for example, a set of generalized diagnostic measures is assessed; blood pressure and pulse rate may serve as indicators of the health of the circulatory system. Although not complete measures, these variables integrate a variety of functions into key measures that act as early warning signs for potential problems. More complete diagnoses using other measures of the circulatory system might follow. When these measures are combined into a total assessment, the person's health can be diagnosed.

A similar approach is useful in aquatic ecosystems, provided we recognize that we may not be able to define as narrow a range of values as for human health characteristics. For example, certain characteristics, such as temperature requirements for salmonids, have clearly defined ranges but others, such as defining the type and amount of pool habitat required for juvenile rearing, may vary widely depending on geology, climate, and predominant vegetation. Because of the dynamic nature of both habitats and populations, we recognized that fixed values or numbers for habitat characteristics and populations are inappropriate (FEMAT 1993).

Researchers in Southeast Alaska and the Pacific Northwest have identified several key habitat attributes that influence the distribution and survival of anadromous fish (table 2) (Meehan 1974, Meehan and Swanston 1977, Sedell and Swanson 1984, Murphy et al. 1984, Bryant 1985). We used several of these studies and our knowledge of some important linkages of life history to habitat in developing an initial suite of key attributes to use in evaluating habitat conditions and stream health in watershed analysis reports.

Table 2--Physical attributes commonly used to measure freshwater salmon and steelhead habitat

Life stage	Attributes
Spawning	Substrate composition, percentage fines, embeddedness
Incubating	Percentage fines, embeddedness, dissolved oxygen, temperature
Juvenile rearing and adult	Pool area, depth, substrate composition, embeddedness, dissolved oxygen, temperature, habitat complexity, cover, large woody debris, width/depth ratio

These key attributes include large woody debris, off-channel flood-plain habitat, substrate composition, channel morphology, measures of health and diversity of salmonid communities, and sediment source from mass wasting. This initial list was evaluated over a 2-month period to determine what information in existing stream-survey data bases could be used to develop interim habitat objectives for Alaska (appendix C.1). We developed the these habitat objectives by using the following rationale.

Large Woody Debris

The size and frequency of large woody debris pieces in the stream channel is a key habitat attribute that could readily be derived for Alaska streams (Bryant 1983, Bryant 1984, Lisle 1986, Robison and Beschta 1990). We decided to use total pieces of large wood per unit area of active stream channel, and stratified by channel type or channel process group as an objective.

Off-Channel Flood-Plain Habitats

Off-channel flood-plain habitat consists of side-channels and sloughs that are connected to mainstem flood-plain channel types during high flow events. Small footslope tributaries fed by shallow alluvial aquifers may also be defined as providing off-channel habitat for salmonids. The amount and condition of off-channel habitats were recognized as key indicators of habitat diversity and productivity in many Southeast Alaska and British Columbia watersheds (Murphy et al. 1984, Hartman and Brown 1987). Determining acres of off-channel habitat is difficult without extensive field traverses through flood plain riparian areas. Off-channel habitat was integral to the design of Riparian Management Areas, but it was not used as an objective.

Substrate Composition

Available spawning area is often used as an indicator of salmonid production potential. Review of stream-survey data showed very high variability in spawning area that is believed to be a function of observer bias. We used Wolman pebble counts (Wolman 1954) to determine the distribution of substrates and size distribution by channel type to assess substrate condition and its relation to fish habitat needs (appendix C.3). Substrate size distribution is strongly influenced by bedrock geology and local erosional processes. We recommend further assessment of substrate distributions by channel type and stratified by bedrock geology before comprehensive substrate objectives are adopted.

Channel Morphology

Pool area and bankfull channel width-to-depth ratio were selected as key attributes. They were measured fairly consistently by stream survey crews and are generally recognized to be useful indices of habitat condition and channel stability (FEMAT 1993, Overton 1993). Other channel morphology attributes identified for future consideration as objectives include wetted channel width-to-depth ratio, maximum pool depth, residual pool depth, mean pool depth, and habitat unit (pool/riffle/glide) area.

Measures of Health and Diversity of Salmonid Communities

Health and diversity were dropped from consideration as quantifiable objectives because of high natural variability in fish populations between watersheds and the cyclic nature of salmonid populations. We believe these data are valuable for monitoring long-term trends in a given watershed. Population surveys to measure species distribution and relative densities of salmonids are recommended to supplement objectives in assessing fish habitat condition.

Sediment Source From Mass Wasting

Sediment delivery from mass-wasting events is a major disturbance factor that affects channel stability and fish habitat condition in Southeast Alaska (Sidle 1980; Hogan 1986, 1987, 1989; Swanston 1991; Swanston and Marion 1991; Swanston and Erhardt 1993). We have not specified an objective for mass wasting, however, because of high variability in its frequency and in sediment delivery rates to streams, and a general lack of comprehensive inventory, monitoring, and research data on the long-term influence of mass-wasting events on channel stability and fish habitat condition. A qualitative risk assessment for mass wasting/sediment delivery was conducted (appendix C.3).

After the range of habitat objectives was narrowed, we conducted a comprehensive analysis of stream survey data. Data from pristine watersheds were used in the analysis to assure that data represented only natural variability in riparian and stream habitat condition. These data were used to set the final range of variability we used in our analyses.

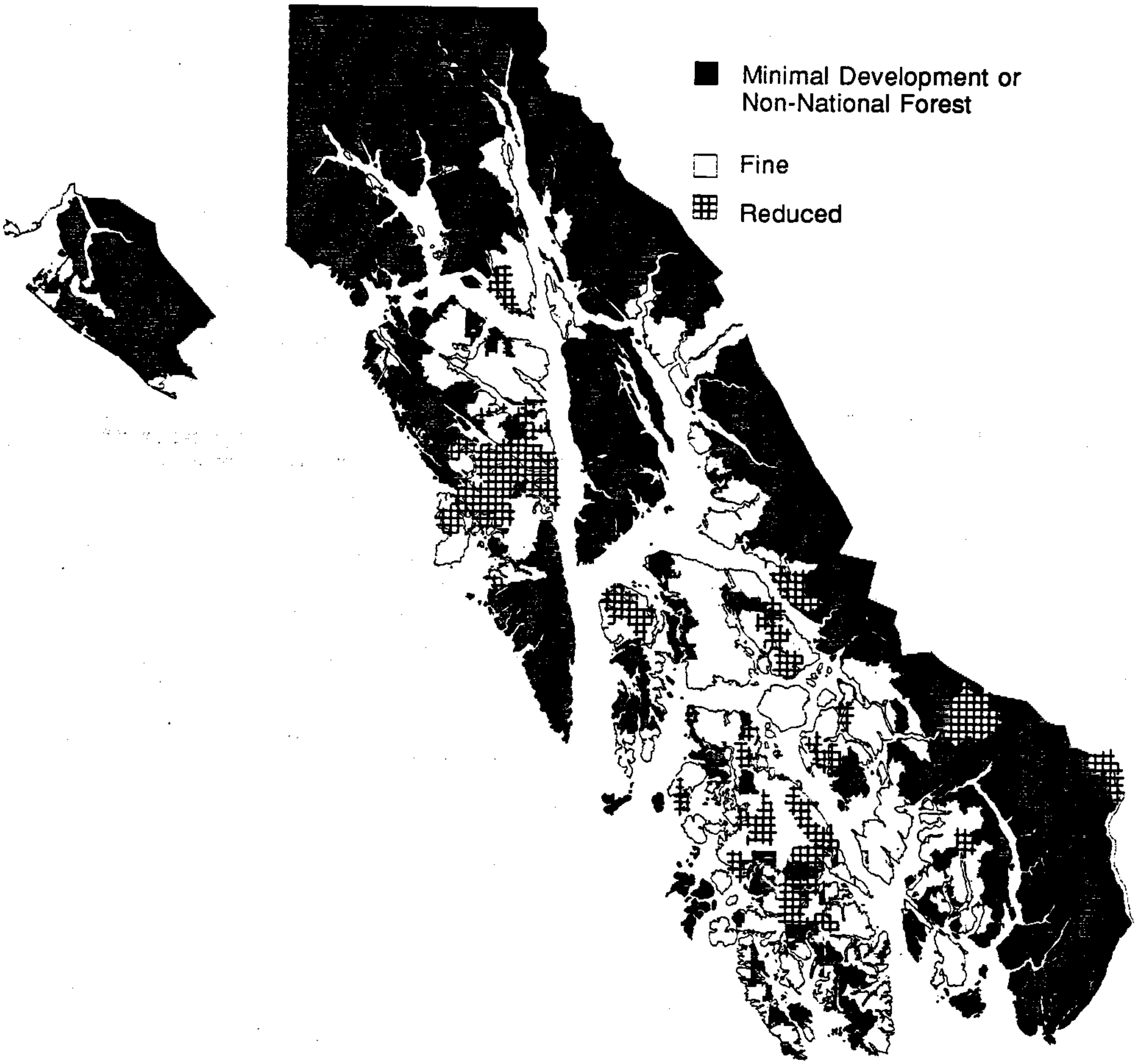
CURRENT WATERSHED CONDITION

A general assessment of watershed condition was completed in 1992 by Tongass National Forest Ranger District staff. The assessment provided a watershed-by-watershed opinion of the conditions. Information from the 11 Ranger Districts of the Tongass was summarized by using four general types of land allocation: wilderness, roadless, variety of uses and outputs, and commodity emphasis. Each type was assigned into two categories: watershed condition currently healthy (conditions and functions generally in balance) or watershed condition not healthy. The biologists and hydrologists working on the assessment based their determinations on information about the natural conditions of the watershed, known changes in riparian conditions or stream habitat, and professional observations and experience (J. Christner, data on file at Tongass National Forest--Chatham Area). Stream class, channel type, management influences (for example, riparian area harvested, minerals activity, or roads), soil hazard rating, and results from a riparian harvest-effects model for coho salmon also influenced their assessments.

For the lands within the Tongass National Forest boundary, including all ownerships, 77% of the watersheds were considered to have a healthy watershed function and condition and 23 percent had a reduced condition. In the categories "variety of uses and outputs" and "commodity emphasis", 72% of these watersheds were classified as healthy, and 28% had conditions with reduced condition. Figure 2 indicates those areas of National Forest Lands (excluding other ownerships) that were rated with watershed function and condition reduced.

Most watersheds with reduced function and condition have been affected by commercial timber harvest operations during the 1950s to 1970s when Best Management Practices were not used. Watersheds managed during the 1980s to 1990s were subject to Best Management Practices. In some places, the watersheds have become Wilderness or legislated roadless since the logging or other activity occurred. What are currently considered best management practices were not in use during the earlier periods when activities such as clearcutting to all channel banks, salvage and removal of natural large woody debris from streams, yarding logs across or through stream channels, extensive road construction in flood plains, inadequate road drainage structure designs, and limited erosion control measures were common.

Figure 2--Watershed condition on the Tongass National Forest



Chapter 3. The Studies

The Fish Habitat Analysis Team (the Team) was chartered by the Alaska Region and Pacific Northwest Research Station to answer the questions in the Anadromous Fish Habitat Assessment Plan dated 28 March 1994. As outlined in the Plan, the Team was to draw on all available information applicable to the two questions, as well as to develop conclusions and recommendations. The Plan said that the Team "will have the authority to independently formulate and conduct the details of its analysis, generally following the process outlined in the Plan."

Forest Service monitoring and evaluation would produce answers to the questions over time, but current practices have not been in effect or been monitored long enough to provide them now. Providing definitive answers in the time alloted required the Team to create a process that incorporated the professional knowledge and experience of the individual Team members with three concurrent studies that we believe support the conclusions outlined in this report:

- A literature review of existing knowledge, drawing on published and unpublished papers on fish habitat and management effects from Alaska, the coastal Pacific Northwest, and British Columbia, and unpublished reports from the Tongass National Forest's District and Supervisor Offices;

- An expert review of selected watersheds where management activities were initated after passage of the Tongass Timber Reform Act. This expert review drew on the best professional judgment of recognized experts to display the trend of watershed condition in selected watersheds under current management over the long term; and

- The reports of Area and Regional Watershed Analysis Teams. The watershed analyses provided a state-of-the-art assessment of existing watershed conditions in three watersheds on the Tongass. As a part of the analysis, Riparian Management Areas were delineated and compared with units actually harvested on the Forest.

The methods used and the results of these studies are discussed in more detail later in this chapter.

The first draft of our report was reviewed by scientists with expertise in fisheries, hydrology, and geomorphology and by each Tongass Area fisheries biologist. The review was kept confidential. The purpose of the review of our draft report was to ensure that the studies were rigorous enough to support our conclusions and respond to the congressional study request.

LITERATURE REVIEW

We reviewed literature on the relation of land management activities to anadromous fish habitats to assist in evaluating current activities on the Tongass National Forest that reflect procedures since enactment of the Tongass Timber Reform Act. The review included peer-reviewed, published literature from professional journals, books, and symposiums; literature from published agency reports, workshop proceedings, and technical reports; non-peer-reviewed, unpublished internal reports, progress reports, and final reports; and unpublished data summaries. The unpublished material we reviewed was limited to items that pertained directly to Southeast Alaska.

Methods

The Pacific Watershed Institute conducted the review under contract with the Team. Various sources for references were used, including existing literature data bases. The contractor visited USDA Forest Service Supervisor and Ranger District offices to review internal reports and unpublished data. The published literature collected was focused on studies from the north Pacific coastal forests of Oregon, Washington, British Columbia, and southeastern and south-central Alaska. Studies from elsewhere were included if they applied directly to Alaska forest and fish habitat management. The subjects emphasized were fish habitat interactions in unmanaged and managed watersheds; monitoring management activities; and evaluating best management practices in aquatic habitat, such as the use of buffer strips and riparian management areas. Some of the limitations of the literature were that the studies had short time frames, were limited in scope, were narrow in focus, did not look at a range of ecosystem processes, and were not normally based on whole watersheds.

A total of 1,542 citations were entered into a computerized literature reference data base, with keywords for each citation. Citations included author, date, title, source, and a concise summary that included objectives, methods, results, and conclusions. Documents not readily available were copied, and filed at the library in the Forestry Sciences Laboratory in Juneau. The data base was used as a tool to examine specific aspects of fish habitat, effects of human-caused and natural disturbances, and effects of various management practices on fish habitat, watersheds, stream morphology, and fish abundance and distribution. This data base was available to the Team, and the information obtained from it is incorporated into the body of this report.

Results

The type and amount of unpublished information available throughout the Region varies widely. An extensive list of stream surveys in the region was available, but the methods and results were not always reported. Numerous reports on site-specific projects or effects are available, including enhancement and rehabilitation projects, evaluation of various landslides and road failures, or windthrow of riparian trees. Monitoring reports for Best Management Practices are listed for all Areas of the Tongass. Best Management Practices implementation has improved throughout the Tongass (USDA Forest Service 1992, 1993), but some concerns about implementation are evident, such as insufficient erosion-control measures. None of the reports has been subjected to peer review, few have been evaluated outside of the unit on which they were prepared, few appear to contain analyzed and interpreted data, and none directly address whether the management practices were effective in protecting salmon and steelhead habitat.

Although no studies directly assess the effectiveness of Best Management Practices or buffers as applied on the Tongass National Forest, studies in landscapes similar to Southeast Alaska show declines in salmonid habitat capability after timber harvest of more than 25 percent of the watershed (Reeves et al. 1993). Harvest treatments included some without streamside buffers, some with retained buffers on fish-bearing streams but with completely harvested headwaters, and others with a mixture of patch cuts in the riparian area (pers. comm., F. Everest 1994; Hall et al. 1987). As a group, these streams incorporated a mix of streamside management that included buffers similar to those currently applied on the Tongass, as well as past Tongass practices. In all of the streams, salmonid habitat quality declined (pers. comm., F. Everest 1994).

Other published literature showed negative effects after timber harvest on unstable slopes and headwater streams (Swanston 1974, Wu and Swanston 1980). Narrow buffers blew down along salmon streams in the Pacific Northwest (Andrus and Froehlich 1992). Although no studies made a direct comparison, the literature showed that streams in Alaska reacted to various disturbances--such as stream cleaning, riparian harvest, and disturbance of headwater streams--in similar ways to streams in similar landscapes in the Pacific Northwest of the United States (Elliott and Reed 1974, Swanson et al. 1987, Hogan 1989).

Throughout this analysis, we frequently referred to the data base and literature to check questions of fact and interpretation and to guide and support our work. The body of this report incorporates the results of the literature review with many specific references.

EXPERT FIELD REVIEW

In this study, we used experts in a structured analysis process to assess the effects on fish habitat resulting from current timber management procedures. This expert analysis also assessed the potential effect of additional timber management activities that are possible under the draft preferred alternative in the proposed revision of the Tongass Land Management Plan. The study was designed following a modification of the Delphi technique (Linstone and Turoff 1975, Martino 1983).

We call this study the expert field review and designed it to allow individual experts to observe procedures being used to protect fish habitat and contribute what they thought pertinent and were comfortable with professionally. The goal was to gather anonymous expert opinions, not to reach consensus among experts on any of the findings. The rationale for this structure was that valid reasons can exist for differences in professional opinions and ratings, and we did not wish to lose any valuable insights. For detailed information on the process and results, see appendix C.2.

Methods

The group of experts consisted of six individuals with expertise in fish biology, hydrology, or watershed processes. Each expert was selected by using criteria established by our Team. (See appendix C.2 for a discussion of the selection process, as well as names and standardized resumés for the individuals selected.) Three of the experts were available for the entire field review, but the other three were only present part of the time.

Seven watersheds were field evaluated by the experts. Watersheds selected for their review were in two sets: those harvested since November 1990 (passage of the Tongass Timber Reform Act (post-Reform Act)), requiring a minimum 100-foot, unharvested buffer on both sides of class I streams and class II streams that flow directly into class I streams; and the watersheds analyzed in the pilot watershed analysis process described later in this document. Post-Reform Act watersheds were selected to avoid experts' conclusions about management effects on fish habitat associated with pre-Reform Act timber harvest practices. Watersheds analyzed in the pilot study (Game, Old Franks, and Kadake) were also selected to assist in our more-in-depth evaluation of three of the watersheds. Old Franks, Upper Thorne, Kadake, Frosty, Whale/Buckhorn, Game, and Seagull were the watersheds selected for study. These watersheds are distributed across the major timber-producing areas of the Forest and represent the range of conditions found in Southeast Alaska for many watershed attributes, such as topography and fish production. Gypsum Creek was also selected, but the group of experts was unable to visit this site because the roads were blocked by windthrown trees. Appendix C.2 includes a discussion of the planning and harvest history for each of the sampled watersheds. Harvest unit layouts for Old Franks, Upper Thorne, and Kadake watersheds were developed after the passage of the Reform Act. Frosty, Whale/Buckhorn, Game, and Seagull all had long histories of planning and layout before Reform Act passage but harvest plans were modified after passage to conform. The experts also visited undisturbed areas before assessing the watersheds to calibrate their thoughts to the natural condition.

We designed a field form for expert use during the field review of watersheds (appendix C.2). Modifications to the original field form were made by the experts before they reviewed the first watershed to help assure consistency of ratings. The forms requested the experts to rate risk to fish habitat (1 to 5, from low to high) for several different habitat parameters based on their observations. The ratings represent the probability of a detectable adverse change in fish habitat quality. Risk of accelerated mass wasting and changes to upland forested and nonforested (palustrine) wetlands function were also rated, but these ratings were not directly tied to fish habitat.

Experts were asked to rate only the categories for which they felt qualified. The experts also commented on probable causes for risk to fish habitat, and made recommendations for monitoring, rehabilitation, and stream-buffer design. Current risk, as well as anticipated risk in 30 and 100 years resulting from the cumulative effects of multiple timber entries, were evaluated. Completed field forms for each of the watersheds (typed to preserve anonymity) are available on request.

All but one expert were comfortable with the rating system and the evaluation process for the watersheds. His comment follows: "I was uncomfortable with the use of numbers and unable to distinguish differences between evaluating risk of an event occurring and risk to fish habitat." Kadake was the only watershed with significant pre-Reform Act timber harvest and roading; experts stated that they tried not to consider pre-Reform Act concerns they observed in their evaluations.

Maps and other factual information were provided to the experts. Map information included contour lines, stream classes and channel types, forested land considered tentatively suitable for timber harvest, wetlands, unstable slopes, very unstable slopes, specified roads, and harvest units (both pre- and post-Reform Act). Other information usually available included unit and road-layout cards, environmental impact statements, and personal interaction with local managers. An over-flight of the watershed was completed before field inspection for all watersheds.

The Team members served as moderators, receiving the information, answering the experts' questions, obtaining clarification of the experts' comments where needed, and summarizing and interpreting the results. Often experts' scores were rather wide-ranging, and Team members had to determine the commonalities between the experts based on their written comments.

None of the results were shared between the experts or outside the Team members before being presented in this report. Neither the experts nor the Team discussed opinions and judgments about the effect of forest management activities on fish habitat at any time during the field work or close-out interviews. Opinions and judgment statements were accepted by the Team from one expert at a time in a controlled setting during close-out interviews.

Results and Recommendations

This section displays the results and recommendations of the experts in three parts: part A summarizes ratings given to individual watersheds, as well as ratings of individual indicators of watershed and fish habitat health and condition across all the watersheds; part B summarizes the experts' opinions about whether current management procedures are effective in protecting fish habitat, derived from three sources--part A, the summary of written ratings after all of the watersheds were reviewed, and our exit interviews with each of the experts; and part C summarizes the experts' opinions about additional recommended procedures for the Tongass, using the same three sources of information.

Part A. Summary Ratings

The experts' ratings given to each of the watersheds, with scores averaged to the nearest whole number, are shown in table 3. The watersheds are shown in the order visited by the expert team. The table shows a considerable range in ratings across watersheds for the **current** conditions: two watersheds were rated as having low risk of a detectable adverse change in fish habitat and watershed condition, five watersheds were rated as moderately low, and one watershed was rated as moderate. Experts' ratings for future risk showed greater consistency: all watersheds were rated at either moderate or moderately high risk in 30 or 100 years with the continuation of timber harvest and roading; all watersheds were rated at low or moderately low risk in 30 years with no additional timber harvest and roading; and all watersheds were rated at low risk in 100 years with no further timber harvest and roading.

Table 3--Experts' summary ratings of the increased risk to fish habitat over natural background risk, by number of experts doing the rating, and by watershed [1]

			In 30 years		In 100 years	
Watershed	**Experts**	**Now**	With	Without	With	Without
Old Franks Creek	5	2	3	2	3	1
Upper Thorne River	5	1	3	1	3	1
Kadake Creek	5	1	3	1	3	1
Frosty Creek	5	2	3	2	3	1
Whale/Buckhorn Cks.	4	2	4	2	4	1
Game Creek	4	2	3	2	4	1
Seagull Creek	4	3	4	2	4	1

[1] This table shows ratings for average risk to fish habitat given by the experts for each of the watersheds. It represents the probability of a detectable adverse change in fish habitat quality. A scale of 1 to 5 was used, with the following risk ratings: 1 = low (≤ 20%); 2 = moderately low (21-40%); 3 = moderate (41-60%); 4 = moderately high (61-80%); 5 = high (≥ 81%).

NOW refers to current risk and risk in the near future. The WITH and WITHOUT columns refer to the experts' evaluation of the potential future risk WITH additional roading or logging and WITHOUT additional roading and logging under current post-Reform Act management practices, given the identification of approximate areas considered tentatively suitable for commercial timber harvest.

At the conclusion of the watershed-by-watershed field review, each expert was asked to prepare a summary evaluation of all the watersheds visited using an additional form. The numerical ratings given for each indicator of health and condition, for every expert, are shown in table 4 (descriptions of the indicators can be found in appendix C.2). Risk to fish habitat, as applied to all the watersheds visited, was also evaluated. Table 4 shows the individual experts' results, as well as an average of their ratings.

Table 4--Experts' summary ratings, based on all watersheds visited, of the increased risk to fish habitat (except for upslope processes) over natural background risk, by indicator [1]

		In 30 years		In 100 years	
Indicator	**Now**	With	Without	With	Without
Upslope processes					
Accelerated mass wasting	2244 **(3)**	3455 **(4)**	2233 **(3)**	4455 **(5)**	1123 **(2)**
Palustrine wetland function	234 **(3)**	245 **(4)**	123 **(2)**	245 **(4)**	113 **(2)**
Hydrology					
Channel morphology/stability	122234 **(2)**	233344 **(3)**	112222 **(2)**	233344 **(3)**	111122 **(1)**
Channel substrate	111234 **(2)**	123344 **(3)**	111222 **(1)**	133344 **(3)**	111112 **(1)**
Water quality (inc. temp, sed)	112233 **(2)**	123334 **(3)**	111122 **(1)**	123334 **(3)**	111112 **(1)**
Habitat (riverine/lacustrine)					
Habitat diversity/accessibility	122233 **(2)**	223444 **(3)**	111223 **(2)**	223344 **(3)**	111113 **(1)**
Buffer function/integrity	122334 **(3)**	223444 **(3)**	112233 **(2)**	224444 **(3)**	111223 **(2)**
Large woody debris	112233 **(2)**	233334 **(3)**	122223 **(2)**	233334 **(3)**	111122 **(1)**
Risk to fish habitat	112234 **(2)**	233444 **(3)**	112223 **(2)**	233444 **(3)**	111113 **(1)**

[1] This table shows the ratings given by the experts after their review of the watersheds; it does not represent the ratings given any single watershed. Ratings are for the increase in risk to watersheds and fish habitat, over the natural background risk, for each of the indicators of health and condition shown. Ratings represent the probability of a detectable adverse change in fish habitat quality. A scale of 1 to 5 was used, with the following risk ratings: 1 = Low (≤ 20%); 2 = moderately low (21-40%); 3 = moderate (41-60%); 4 = moderately high (61-80%); 5 = high (≥ 81%).

Each experts' individual score is shown, as well as the average of the scores in parentheses ( ). Blocks with fewer than six numbers indicate that one or more experts did not feel qualified to rate that indicator.

NOW refers to current risk and risk in the near future. The WITH and WITHOUT columns refer to the experts' evaluation of the potential future risk WITH additional roading or logging and WITHOUT additional roading and logging under current post-Reform Act management practices, given the identification of approximate areas considered tentatively suitable for commercial timber harvest. Note that the upslope processes (first two rows) are evaluated independently of their effect on fish habitat.

The experts recognized a moderately low increased risk of a detectable adverse change in fish habitat over the natural background now, but the increases in risk varied greatly by expert (from a rating of 1 to 4). For future periods, all experts anticipated an increase to moderate risk with continued timber harvest and roading, using current procedures, and to low or moderately low risk with no further timber harvest and roading.

Part B. Evaluation of Current Procedures

All of the experts provided summary ratings; five of them were also available for close-out interviews at the conclusion of the field review. At the interview, each was asked the question, "Are current management procedures on the Tongass National Forest effective in protecting fish habitat?" They all indicated that additional protection measures are necessary to fully protect fish habitat. The unanimity of this opinion was also evident in their statements and ratings for each of the individual watersheds (see appendix C.2).

Concerns expressed by one or more experts are listed below to explain the reasons for their evaluations of effectiveness. A summary of their recommendations for improved procedures to address these concerns is in part C. Note that although the good practices observed by the experts were discussed, this listing is not comprehensive because the experts were not specifically asked to list good practices, although they were asked to list their concerns.

Class I and II stream buffers. Stream class I and II buffers were sometimes observed to be too narrow. The experts stated that many buffers on class I and II streams need to exceed the minimum 100-foot requirement, particularly on large flood-plain channel types where the streams meander over time and often cover distances exceeding 100 feet from the main channel. Buffer design must match the site topography and remain windfirm, or buffer function will be reduced through changes in shading for microclimate control, nutrient input, and long-term recruitment of large woody debris. Significant windthrow was observed in many areas harvested during the last 1 to 3 years. To balance the observations of less than adequate buffers, many other buffers were found to be sufficient to protect the interactions that exist between the stream and the adjacent terrestrial systems. This observation was particularly true at those sites where field personnel were given the most flexibility by managers in designing buffers.

Buffers on class III streams. More no-harvest buffers are needed on class III streams and some unclassified channels or fish habitat will be adversely affected. Impacts are due to loss of the supply of large woody debris that is important for the entrapment of sediment, slower movement of that sediment through stream systems, and as a source of large wood and nutrient input to downstream fish habitat. One expert stated: "Because class III's are open conduits to downstream fish habitat, sediment will flush down to fish habitat during big events and affect fish habitat. It may take a long time to get there, but it will get there." The experts were unanimous in the need for more buffers on class III streams, but no consistent recommendations were made on the design of the buffers (such as exactly how wide the buffers need to be or the specific circumstances where they are needed).

Activities on unstable slopes. Harvesting timber on unstable slopes with soils rated high or very high for mass movement will generally accelerate mass wasting and transport sediment to fish streams, primarily via the small intermittent channels. Risk to fish habitat is from aggradation in stream beds and channel widening. Surface erosion processes seemed well protected through harvest techniques and Best Management Practices, but shallow mass wasting is the dominant process likely to deliver significant amounts of sediment to downstream channels. Loss of root strength after clearcut harvest and increased runoff from reduced evapotranspiration are the factors primarily contributing to anticipated loss of slope stability and increases in mass wasting. Concern was most often expressed about activities on the steep slopes observed on the Chatham Area of the Tongass.

Road location, design, and management. Mid-slope roads cause changes in channel morphology and substrate through chronic and acute (such as landslides) introduction of road material from cuts and fills to stream systems. Location and design of roads through wetlands has resulted in roads intercepting and re-routing wetland runoff. This re-routing causes concentration of water in road ditches and may affect wetland water tables and increase peak flows. Failures to implement some of the Best Management Practices associated with road drainage design and maintenance were identified as increasing the risk.

Problems where road culverts adversely affect the productivity and accessibility of fish habitat were identified. Problems noted by the experts included undersized culverts installed in ways that did not assure fish passage, use of round culverts which often impede fish passage, inadequate numbers of road drainage structures, and the accumulation of materials above culverts that can lead to the failure of crossing structures and road beds during large runoff events. Many times, the experts mentioned inadequate maintenance of road drainage systems and inadequate close-out of temporary roads as potential mechanisms for road failure and delivery of sediment to fish habitat.

Variability in implementing guidance. Several experts expressed concern over the apparent variability in interpreting guidance by different staff implementing timber-sale and roading projects. Included in this concern were problems associated with recognizing and classifying stream channels for buffer protection and determining where to start buffer measurements. Most Districts had a process to incorporate new information, such as previously uninventoried streams, and placed them on harvest-unit cards, but this practice was not universal. Inaccurate inventory information and untimely updating of the corporate data base with information gathered during harvest layout were identified as problems.

Part C. Recommendations

The experts provided recommendations on changes in management practices to reduce the risk to fish habitat, both in their written material and during interviews at the conclusion of the field review. These recommendations are summarized as follows:

Stream buffers. Buffer design should consider fish habitat, and water and sediment routing, rather than just the presence or absence of fish species. Buffers should also match the site topography, and those associated with flood plains managed to at least the borders of the active flood plain. Buffers should be designed to remain windfirm. Generally, 100-foot buffers are not sufficient on larger, unconfined class I and II streams to meet these needs. Numerous suggestions were made on how to size the width of buffers to retain the buffer function, considering the amount of windthrow in Southeast Alaska. Recommendations ranged from maintaining an additional 25% width of the needed "functional" buffer size, to incorporating entire flood plains plus 100 additional feet. Recommendations were also made that no harvest occur in areas of extreme windthrow hazard. Salvage of windthrown timber in buffers should not be allowed because the windthrown trees function to break-up the force of wind as it approaches the remaining standing timber and provide nurse logs for tree regeneration.

Experts unanimously stated that buffers on class III streams were needed; however, no consensus was apparent on a prescriptive remedy. Comments made by the various experts clearly indicate that no "cookbook" answers exist for buffer design on class III streams. Opinions ranged from a minimum 100-foot no-harvest buffer on all class III streams to recommending that only the sensitive portions (for example, unstable areas) of the class III streams be buffered. Most experts recommended some form of buffers on unclassified streams, and one expert warned, "It seemed clear that in some areas, thin buffers on small headwater channels are vulnerable to blowdown. This will have complex and unpredictable effects on fish habitat in the long term." Recommendations for research and experimentation were offered.

Activities on unstable slopes. The experts recommended that timber harvest and roading activities on potentially unstable slopes be reduced or eliminated. Some of the experts thought that selective timber harvest may be possible, but considered clearcut harvest methods that disturb large areas to be very risky. Potentially unstable slopes generally include those at greater than 40 degrees and topographic hollows steeper than 35 degrees, although lower slope angles can be at risk, depending on soil types.

Road locations, culverts, and road/culvert maintenance. Most of the experts recommended that roads should not be constructed on potentially unstable areas, including both the high and very high mass-movement-hazard categories. The experts also recommended that more attention be given to construction techniques across wetlands (so as not to damage their hydrologic characteristics), location of cross-drains (discharge should be on undissected hillslopes to reduce direct routing to stream channels and resulting increased peak flows), and passage requirements for fish. Several experts suggested that round culverts be used only rarely in designing for fish passage. Several experts also commented favorably on the use of log sills below culverts (observed several times) to reduce the potential for culvert outlets to become impassable waterfalls.

Inadequate road maintenance was a frequent concern of the experts. In particular, they were concerned about blockages of culverts, which can lead to failure of structures and the road prism. Some recommended annual road and culvert monitoring, and immediate monitoring during and after significant storm events. Closure of more roads, including the removal of drainage structures and seeding of road beds, would reduce annual monitoring and maintenance costs and reduce potential sediment input to streams.

Variability in implementation of guidance. Considerable variation in implementing guidelines was seen throughout the Forest. On some timber sales, the minimum 100-foot buffers were often the extent of protective measures and resulted in increased risk to fish habitat; on others, however, the additional efforts that went into design provided considerably reduced risk. Sales planned more recently (Old Franks, Upper Thorne, and Kadake) generally had lesser risk. Although they recognized that some of the timber sales were in more forgiving terrains than others, the experts generally agreed that implementation could be improved through better training, use of specialists, and increased understanding of geomorphic processes. Experts recommended that additional fish biologists, hydrologists, and geomorphologists participate in design and layout decisions for roads, harvest units, and buffers. They also suggested that all field personnel be provided training in hydrology and geomorphology to identify unstable slopes and routing mechanisms of large woody debris and sediment to fish habitat.

The experts recommended obtaining more-accurate inventory data, consistent across the Tongass, and developing an improved process to update the electronic data bases. They also made monitoring recommendations for the Tongass, which included implementation, effectiveness, and validation monitoring suggestions. A listing of their monitoring recommendations is in appendix C.2.

WATERSHED ANALYSIS

Watershed analysis is a systematic procedure for developing an understanding of the physical (and some of the biological) processes taking place in a watershed. The analysis measures key land and water attributes and describes the geomorphic and fluvial processes, current and desired watershed condition, and delineates the sensitive riparian areas in a watershed.

The congressional Conference Committee Report on the 1994 Appropriations Act directed the Forest Service to study the effectiveness of current procedures to protect fish habitat. The goals of using a watershed analysis approach were to:

- Assess the current fish habitat conditions on a range of Tongass National Forest watersheds by using the interim Tongass-wide Fish Habitat Objectives (appendix C.1);

- Compare the way harvest unit layout could have been designed after a detailed watershed analysis with the unit layout applied on the Tongass National Forest; and

- Evaluate the usefulness of watershed analysis as a foundation for developing effective riparian conservation strategies.

Methods

An Area Watershed Analysis Team (Area Team) was formed on each Tongass National Forest Administrative Area to do the analysis. An overview team (Regional Team) with interagency representation was also formed for coordination and technology transfer. The Regional Team adapted the procedures outlined in *A Federal Agency Guide for Pilot Watershed Analysis* (1994) to meet our needs for responding to the congressional study request. The Regional Team reviewed river basin and regional-scale fish habitat issues and identified key questions about how management activities affect the hydrologic cycle, sediment budget, wetland functions, water quality, and anadromous fish habitat in Southeast Alaska. This analysis covered fish-related resources but did not include wildlife or social considerations. This section is based on information from three sources: the individual Area watershed analysis reports, interviews with Area Team leaders, and the Regional Team summary report (appendix C.3)

We required that the watersheds selected for this analysis be covered by a post-Reform Act Record of Decision (or a pre-Reform Act Record of Decision modified to meet the requirements of the Act); have a substantial amount of class I stream habitat; and be more than 10 square miles. Forty-eight potential watersheds were considered. The three watersheds selected for analysis (Game Creek, Old Franks Creek, and Kadake Creek) represent a range of completed timber harvest intensities and geoclimatic conditions typical of the Tongass National Forest. Selection was the result of a consensus of the Regional Team, our Team, and the Alaska Working Group on Cooperative Forestry/Fisheries Research, with input from the Sealaska Corporation, the Alaska Department of Environmental Conservation, and the Alaska Department of Fish and Game. The three watersheds were:

- *Game Creek* (Hoonah Ranger District, Chatham Area) watershed is about 48 square miles; the lower 12 square miles is in private ownership. Currently 1,545 acres (5%) of the watershed has been harvested. Timber sales have occurred on 29 harvest units on National Forest lands. Five of these units were harvested before the Reform Act; 24 were harvested in 1993 after passage of the Reform Act. Minimal harvest has been done on the private lands in the watershed.

- *Kadake Creek* (Petersburg Ranger District, Stikine Area) is about 50 square miles. Currently 4,700 acres (15%) of the watershed have been harvested. Twelve post-Reform Act units have recently been authorized for timber harvest under the North and East Kuiu Final Environmental Impact Statement and Record of Decision. A portion of these units has been harvested, and the remainder may be available as independent timber sales in the future. About 50 harvest units and their associated roads have been developed under pre-Reform Act Records of Decision.

- *Old Franks Creek* (Craig Ranger District, Ketchikan Area) is about 25 square miles; the lower 9 square miles (below the lakes) is in mixed ownership. Currently, 540 acres (6%) of National Forest lands in the upper watershed has been harvested. Eight post-Reform Act units were harvested in 1992 and 1993, in accordance with the Record of Decision for the 1989-94 long-term sale. Thirteen more units in the upper watershed are proposed for harvest in Alternative 5 of the Polk Inlet Environmental Impact Statement.

These watershed analyses are "snapshot" condition assessments after harvest of relatively small portions of the watersheds. They do not assess potential cumulative effects. Without baseline data, cause and effect relations are difficult to describe; the expert field review was needed to help address possible long-term changes in these watersheds. The riparian habitat conservation strategy (A Federal Agency Guide for Pilot Watershed Analysis 1994) identifies Riparian Management Areas, provides guidance for planning activities within these areas, describes restoration and monitoring needs, and identifies information needed for project analysis. The focus of this analysis was primarily to delineate Riparian Management Areas and describe their functions and sensitivities.

Using A Federal Agency Guide for Pilot Watershed Analysis as a reference, we adapted or developed protocols for collecting and analyzing data (see appendix C.3). These protocols standardized the analyses on the three selected watersheds. These analyses mostly used an existing data base stored in a geographic information system (GIS) that was adjusted by field review to validate and update existing inventories. The data layers used in these analyses included digital elevation models, geology, soils, harvest units, streams, roads, and vegetation type.

Fish habitat data on each watershed were compared to the interim Tongass-wide Fish Habitat Objective values developed by our Team (appendix C.1). These interim objectives were viewed primarily as benchmarks to use in assessing fish habitat conditions in a given stream segment. Three sets of habitat objectives were defined and used for the pilot watershed analyses--pieces of large woody debris within a 1,000 m^2 channel area, percentage of pool area, and channel width-to-depth ratio. A specific set of habitat objectives was developed for stream process groups and some channel types. The channel-type classification categorizes stream segments that are influenced by similar geomorphic and riparian processes, and have similar morphology and attributes of fish habitat (appendix C.1, table 1-A).

Several factors were considered in comparing the fish habitat objectives with habitat measurements. Some of the benchmark data sets from pristine watersheds are small and may not always be representative. Pool area estimates have a relatively high sampling error (see appendix C.1). Width-to-depth indices were given the most weight, and percentage of pool area values were given the least weight in assessing fish habitat condition. A qualitative rating of habitat condition (ranging from poor to excellent) was assigned to each habitat objective by comparing measured values from each watershed (compiled by channel type or process group) to 25th, 50th, and 75th percentile values for large woody debris frequency, percentage of pool area and width-to-depth ratios measured in pristine watersheds (tables 5 and 6).

Results

Instream Condition Assessment

Fish Habitat Objectives--Habitat condition for many objectives was rated average or above average for the three watersheds (tables 5 and 6). With the possible exception of Kadake Creek, the stream survey data suggest that current fish habitat is in relatively good condition in the three watersheds, and the habitat has not been degraded by current management practices.

Game Creek watershed has very large amounts of woody debris and favorable width-to-depth values for all channel types surveyed. Two Game Creek channel types (FP4 and MM2) have average or above average pool area. The FP3, FP5, and MM1 channel types have below average pool area; however, stream survey data indicate a relatively high pool frequency for most stream segments in Game Creek.

Pool habitat on Kadake Creek is consistently above average, but large woody debris is generally below average. Width-to-depth ratios for flood plain channel types on Kadake Creek are well above the median,

Table 5--Comparison between watershed-analysis habitat measurements and the Interim Tongass fish habitat standards for pools and large woody debris

Fish Habitat Objective	Process groups/ channel types[1]	Interim Tongass habitat standards (percentiles)[2]			Measured habitat values[3]		
		25th	50th	75th	Game Creek	Kadake Creek	Old Franks Creek
Large woody debris, pieces/1,000 m²	FP3	10	32	54	96 (1.3)	**30** (1.4)	-- --
	FP4	8	24	34	46 (1.5)	**10** (3.3)	**12** (1.3)
	FP5	4	5	6	21 (2.8)	**2** (7.7)	18 (2.1)
	LC and MC	6	15	22	20 (0.4)	**11** (2.4)	**8** (0.5)
	MM1	27	45	82	96 (0.4)	110 (2.0)	-- --
	MM2	33	35	44	42 (1.7)	**26** (4.2)	-- --
Pool area, %	FP3	20	53	76	**45** (1.3)	75 (1.4)	-- --
	FP4	35	47	59	50 (1.5)	69 (3.3)	71 (1.3)
	FP5	47	51	60	**37** (2.8)	69 (7.7)	58 (2.1)
	LC	8	20	27	39 (0.4)	64 (1.2)	62 (0.3)
	MC	11	22	39	-- --	29 (1.1)	22 (0.2)
	MM1	28	40	52	**18** (0.4)	56 (2.0)	-- --
	MM2	2	22	39	33 (1.7)	39 (4.2)	-- --

[1] Process group codes and descriptions are in table 1-A of appendix C.1. Alpha codes define process-group category, and numeric codes define distinct channel types within each group. Channel types listed include: FP3, small flood plain; FP4, medium flood plain; FP5, large flood plain; MM1, moderate-gradient, mixed-control; and MM2, medium moderate-gradient unconstrained.

[2] Fish habitat objectives are expressed as a range of values based on the 25th, 50th (median), and 75th percentiles for a given channel type or process group (see appendix C.1). Key for interpreting Interim Tongass pool and large woody debris fish habitat standards: <25th, poor habitat; >25th and <50th, below average habitat; >50th and <75th, above average habitat; >75th, excellent habitat.

[3] Values are watershed summaries for all surveyed process groups or channel-type stream segments. Numbers in parentheses represent surveyed stream length in miles. Dashes (--) represent channel types not sampled. Habitat values in bold represent below average or poor habitat condition based on interim standards.

Table 6--Comparison between watershed-analysis habitat values and the interim Tongass fish habitat standards for channel width-to-depth ratio

Fish Habitat Objective	Channel types[1]	Interim Tongass habitat standards[2] (percentiles)			Measured habitat values[3]		
		25th	50th	75th	Game Creek	Kadake Creek	Old Franks Creek
Stream width-to-depth ratio (dimensionless)	FP3	8	13	18	11 (1.3)	**48** (1.4)	-- --
	FP4	16	25	35	20 (1.5)	**48** (3.3)	**31** (1.3)
	FP5	30	45	70	32 (2.8)	**55** (7.7)	**49** (2.1)
	MM1	9	12	18	**7** (0.4)	**13** (2.0)	-- --
	MM2	17	24	33	**15** (1.7)	**28** (4.2)	-- --

[1] Codes and descriptions are in table 1-A of appendix C.1. Alpha codes define process-group category, and numeric codes define distinct channel types within each group. Channel types listed include: FP3, small flood plain; FP4, medium flood plain; FP5, large flood plain; MM1, moderate-gradient, mixed control and; MM2, medium, moderate-gradient, unconstrained.

[2] Fish habitat objectives are expressed as a range of values based on the 25th, 50th (median), and 75th percentiles for a given channel type or process group (see appendix C.1). Key for interpreting interim Tongass channel width to depth ratio fish habitat standards: >75th, poor habitat; >50th and <75th or <25th, below average habitat; >25th and <50th, above average habitat.

[3] Values are medians for all channel-type stream segments surveyed. Dashes (--) represent channel types not sampled. Numbers in parentheses represent surveyed stream length in miles. Habitat values in bold represent below average to poor habitat condition based on interim standards.

which may indicate some channel aggradation associated with sediment loading from recent landslides in the watershed and less than optimal fish habitat conditions on Kadake Creek. We speculate that high width-to-depth values and low large woody debris accumulation in the mainstem and major valley tributaries of Kadake Creek may be attributed to recent large flood events (see appendix C.3). We cannot determine if past or current management activities may have exacerbated the effects of these flood events because of limited pre-harvest data.

Pool habitat on Old Franks Creek is above average on all streams. Large woody debris on Old Franks Creek is slightly below average for channel type FP4 and contained process-group segments (LC and MC), but large woody debris is abundant in FP5 channel segments. Width-to-depth ratios for Old Franks Creek are above the median, indicating potential sensitivity to sediment loading.

Windthrow--Windthrow is a natural process on the Tongass National Forest because of frequent gales, and it is a major cause of extensive forest disturbance in both Game Creek and Kadake Creek watersheds. Some of the high woody debris loading in streams is due to buffer windthrow. The amount of large woody debris in some segments of the Game Creek flood plain is well beyond the 75th percentile. The edges of some harvest units on Old Franks Creek have also had some windthrow.

Fish passage--Criteria were established for upstream passage of juvenile salmon and steelhead. Conditions suitable for upstream passage of juvenile salmon, steelhead, and trout were assumed to pass adult fish upstream also, but exceptions may occur. No major obstructions to fish passage resulting from management activities were noted in any of the three watersheds. Minor obstructions were identified in the Kadake Creek watershed where two culverts on pre-Reform Act road segments did not meet the passage criteria.

Water quality (macroinvertebrates)--Water quality was indirectly assessed in two watersheds by collecting and analyzing the insect communities (macroinvertebrates) in the stream gravel. Most streams with reasonable water quality and substrate conditions support a diverse population of aquatic insects and other macroinvertebrates. Macroinvertebrate ar generally accepted as useful indicators of water quality. From our macroinvertebrate analyses, no indication was found that water quality in these watersheds is impaired (table 7). This assessment was not conclusive because macroinvertebrates are not a completely reliable indicator of fish habitat. Trends are also unknown because no prior measurements are available.

Riffle stability index--The results of substrate sampling indicate possible moderate to high aggradation in all three watersheds, especially on the lower reaches near tidewater. Two of the watersheds may have been affected by recent storm flow events (Kadake Creek, a 50-year event; Old Franks Creek, a 20-year event) that might have influenced riffle stability values; Game Creek had a high riffle stability index value without a recent high flow event (table 8). The calculated riffle stability index may reflect disturbance caused by recent storm events or naturally high aggradation potential. This index, however, has not been calibrated as a reliable indicator of watershed stability in Southeast Alaska.

Headwater Condition Assessment

Erosion and sediment delivery--Landslides are a common and natural source of sediment in Southeast Alaska watersheds. Relatively few large landslides were inventoried in either Game Creek or Old Franks Creek watersheds (table 9). In Game Creek, although landslides smaller

Table 7--Summary of biological water-quality indices for Game Creek and Kadake Creek

Sample sites	Rapid bioassessment[1]	Biotic condition index[2]
Kadake Creek stations:		
Mouth	3.75	81
S. Fork	3.50	100
W. Fork	3.75	88
Unit 4	3.75	88
Unit control	3.75	96
Game Creek stations:		
Mainstem	3.75	93
N. Fork	3.75	87
SE. Fork	3.50	83
SW. Fork	3.75	86
S. Fork control	3.75	79

[1] Key to rapid bioassessment rating: 2 = moderate impairment, 3 = slight impairment, 4 = no impairment (Milner and Oswood 1991).

[2] Key to biotic condition index: 72-79 = fair, 80-90 = good, >90 = excellent (Winget and Mangum 1979).

Table 8--Summary of pilot watershed-analysis channel-stability ratings[1]

	Riffle stability index by channel type[2]					
Watershed	FP5	FP4	FP3	MM1	MM2	LC1
Old Franks Creek	100	85	--	77	--	96
Game Creek	88	94	77	79	--	--
Kadake Creek	87	89	--	75	86	80
All sites (wt. mean)	93	89	77	81	75	88

[1] Index ratings: < 70 = dynamic equilibrium, 70-90 = approaching geomorphic threshold, > 90 = watershed out of balance (Kappesser 1993). Dashes represent channel types not found in the watershed.

[2] Codes and descriptions are in table 1-A of appendix C.1. Alpha codes define process-group category, and numeric codes define distinct channel types within each group. Channel types listed include: FP5, large flood plain; FP4, medium flood plain; FP3, small flood plain; MM1, moderate-gradient, mixed control; MM2, medium moderate-gradient unconstrained; and LC1, large constrained.

than the 1/2-acre minimum size established in the landslide protocol (appendix C.3) have occurred in harvest units in headwater basins, none of them appear to have reached or entered streams. An increase in sediment delivery is expected over the next few decades in Game Creek, as the strength of dead tree roots declines and the potential for small landslides increases.

Five landslides were observed in the upper Old Franks Creek watershed but only two of them were in the last 25 years. One landslide associated with a harvest unit appears to be related to a 1993 flood. This slide did not reach any stream, but fine sediment is entering streams by way of the road drainage system. Rills and other signs of active erosion and sediment delivery are common on road cut-slopes on unstable soils. Landslides may be a future concern based on the frequency of inventoried unstable soils. Field analysis, however, has not been sufficient either to verify or change soil mass-movement hazard ratings and to assess how serious this concern is.

Landslides appear to be a major source of sediment in the Kadake Creek watershed. Fifty-seven landslides were inventoried. Four of these originated in harvest units, and one consists of spoil material stripped from a rock pit. The remaining 52 landslides are outside of managed areas. Kadake Creek appears to have a high risk of accelerated sediment deposition in class I and class II channels, based on about forty (70%) of the landslides reaching streams (table 9), unstable soils in portions of the upper watershed, and apparent aggrading conditions in the mainstem. Landslides associated with a large rain-on-snow flood in 1988 appear to be a major source of sediment.

Erosion associated with road cut and fill slopes (table 10) appears to be less of a concern than the existing or potential erosion from landslides. Poor cross-drain function on 7 to 13% of the road culverts surveyed in Game Creek and Kadake Creek watersheds (table 10) could result in increased sediment delivery to streams in the future.

Table 9--Summary of landslide survey information for watershed analyses

Watershed	Total slides (number)	Total landslide area (acres)	Slides in harvest areas (number)	Slides reaching streams (number)
Old Franks Creek	5	11	1	0
Game Creek	2	1	2	0
Kadake Creek	57	113	4	40

Table 10--Summary of road-erosion survey information for watershed analyses

Watershed	Road (miles/mile²)	Roads surveyed (miles)	Road cut/fill erosion (acres)	Cross-drain function[1]	
				Yes	No
Old Franks Creek	0.67	11.0	0.15	206	4
Game Creek	0.81	14.5	0.94	207	27
Kadake Creek	1.50	35.7	1.31	761	59

[1] Cross-drain function: **Yes**, cross-drain culverts open and functioning and **No**, cross-drain culverts plugged or missing.

Evaluation of Current Procedures

A Riparian Management Area was delineated in each watershed to identify the riparian, wetland, and sediment-source areas directly or indirectly affecting salmonid habitat. The Riparian Management Areas are a fundamental component of the riparian habitat conservation strategy for each watershed. Current management procedures were compared with fish habitat-protection measures that could have come from applying this strategy. Following is a discussion for each watershed.

Game Creek--Most timber harvest in the Game Creek watershed has occurred since passage of the Reform Act. About 27% of the area harvested is on riparian or potentially unstable soils in the Riparian Management Area (see appendix C.3). Currently, fish habitat does not appear to be impaired; however, continued management activity in riparian management areas could increase the risk of cumulative watershed effects.

On Game Creek, some prescriptions that would have been derived from the riparian habitat conservation strategy could have been different than the ones implemented. For example, a silvicultural prescription in the Riparian Management Area could have recommended that (where stand conditions allow) the buffer be feathered to help maintain the core riparian areas, and timber harvest and road construction be minimized on potentially unstable soils (Mass Movement Index 3-4).

Kadake Creek--In the Kadake Creek watershed, about 6% of the post-Reform Act harvest-unit area is within the Riparian Management Area. The Stikine Area Team concluded that applying a riparian habitat conservation strategy for Kadake Creek could have caused some adjustments on post-Reform Act units, if the strategy had been available during the original planning. For example, Unit 402-16 would probably have received more consideration for preventing windthrow in the buffer along one moderate-gradient, mixed-control (MM1) class II stream perpendicular to the prevailing wind. The buffer could have been feathered, tapered on the abrupt windward face, or the unit dropped.

About 28% of the south subwatershed of Kadake Creek has been harvested in the past 20 years; this percentage represents an equivalent harvest of 17% (the term "equivalent harvest" reflects an adjustment based on hydrologic recovery as a clearcut ages, McCorison et al. 1989). Historically, about 7.5 miles of small class I and class II streams have been harvested along one or both sides of streams in the Kadake Creek watershed (from a total of 168 miles of streams). The large woody debris component is low and width-to-depth values on Kadake Creek are high. These conditions have raised concerns about potential cumulative watershed effects from past land management activities.

Old Franks Creek--The Old Franks Creek watershed has had a small amount of post-Reform Act harvest. About 6% of upper Old Franks Creek watershed has been harvested, but 52% of the area harvested is within the Riparian Management Area on soils that are shown on the inventory as being potentially unstable (Mass Movement Index 3). Most post-Reform Act units lie partially or totally within the Riparian Management Area, which indicates that, with a riparian habitat conservation strategy, the sale would probably have had a different unit layout and timber harvest prescriptions that would provide more fish habitat protection. If the conservation strategy had been available during the planning of the post-Reform Act sale units in Old Franks Creek watershed, the total area in sale units would probably have decreased. Most of the change would likely have been in Unit 613-106 because of mass-movement and sediment transport concerns. In addition, the strategy would likely have modified the road layout and prescriptions on potentially unstable soils, and also changed leave-tree requirements along class III streams.

What Watershed Analysis Brings to Project Planning

Full development of the watershed analysis approach requires more complete and accurate resource information on a watershed scale than is currently used in project planning. By using the watershed analysis approach, we can provide more complete protection of fish habitat and watershed function than currently provided through timber sale planning. The results of watershed analysis can provide land management planners with a better understanding of the current watershed and riparian condition and more complete knowledge about the important processes and functions that influence responses to natural and human disturbances. Watershed analysis can improve land management planning because it provides a means for better evaluating management activities. This improvement could result in better disclosure of environmental effects to Forest Service managers and the public.

Logging system and transportation plans are the primary foundation for current timber-sale project plans. Current planning is often too narrowly focused on the design of individual harvest units and road segments, so the interdisciplinary team has difficulty addressing broad ecosystem management and cumulative effects issues. Current project planning relies heavily on information from reconnaissance resource inventories. Time and resources needed to validate these reconnaissance inventories and to collect site-specific information are often limited during project planning. The practical opportunities for adjusting unit and road designs during layout, to mitigate problems or concerns missed in planning, are somewhat limited. Watershed analysis provides a mechanism to interject essential information on watershed and fish habitat characteristics into the "front end" of project planning, and also provides a structured framework for updating needed resource inventory information in a timely manner. For example, in chapter 7 of the Game Creek Watershed Analysis, the Riparian Management Areas are displayed with the productive forest lands to show the degree of concern for aquatic habitat and define which areas would need to be evaluated most carefully when harvest is being planned.

Watershed analysis takes a broad geographic perspective that provides a context for evaluating the relation between past activities, proposed activities, and the riparian management areas that need to be protected to maintain important riparian functions and fish habitat capability. The riparian habitat conservation strategy is a more specific expression of resource considerations for protecting water quality and fish habitat on class II and III streams than is currently available in the project planning. Watershed analysis provides a tool to better identify potential geomorphic concerns and protect fish habitat.

Summary and Conclusions

Conducting these three watershed analyses facilitated a close examination of important geomorphic processes at the watershed scale. Fish habitat protection procedures, as currently applied on the Tongass National Forest, tend to focus narrowly on local and specific site factors. Watershed analysis and the resultant riparian habitat conservation strategy offer a formal framework to guide designing and implementing the wider scope of resource protection measures needed to provide a high degree of protection for fish habitat.

In comparing activities that might have been designed on the three watersheds under a riparian habitat conservation strategy with post-Reform Act management procedures currently being applied on the Tongass National Forest, the Team found these differences:

- Significant portions of the proposed Riparian Management Areas have been harvested; total area of overlap is 6% for Kadake Creek, 27% for Game Creek, and 52% for Old Franks Creek watershed.

- Riparian Management Area delineation identifies more clearly and completely (than current practices do) the sensitive riparian areas, contributory wetlands (fens), and sediment source areas throughout the watershed that can influence downstream fish habitat.

- The riparian habitat conservation strategy provides for more scrutiny of, and emphasis on, riparian-dependent resources and stream processes than do current procedures, especially resource-protection needs adjacent to class III streams.

- Some silvicultural prescriptions for harvest within the Riparian Management Area would probably have been different from the management prescriptions that were implemented.

Chapter 4. Adequacy of Current Procedures and Recommendations

QUESTION 1: ARE CURRENT PROCEDURES EFFECTIVE FOR PROTECTING FISH HABITAT?

Current procedures for protecting fish habitat have clearly improved the treatment of anadromous fish streams and provided improved protection for valuable stream habitat compared to previous procedures. How effective current procedures actually are often depends on how well existing guidelines were interpreted and practiced on the ground. Analysis of the results of the several parts of this study has shown deficiencies in both current practices and current procedures for protecting fish habitat that could have long-term adverse effects on salmonid populations on parts of the Tongass National Forest. In this chapter, application of current pratices on the ground and the direction and guidelines for providing for fish habitat (procedures) are considered together under the combined discussion on current procedures.

Based on the information displayed, we determined that current procedures, as implemented, are not entirely effective in protecting fish habitat. A common element that appears throughout the analysis is that existing guidelines are not implemented consistently throughout the Forest. In addition, the Tongass Timber Reform Act and current procedures do not address fish habitat and watershed processes over long time frames and over large landscape scales. Our review and comparison of current procedures to various proposed procedures also showed a lack of measurable criteria against which to measure the effectiveness of existing guidelines.

Current procedures were not found to be completely effective, and risk to fish habitat remains. Procedures were found to be less than adequate in five ways: inventory and classification of fish habitat and streams, and protecting their associated riparian areas and wetlands; timber harvest on steep and unstable slopes; road design, mitigation, maintenance, and closure; problems with certain aspects of forest and timber-sale planning; and institutional concerns. We observed that these problems do not always exist across the Forest; in some locations, some of the procedures were found to be adequate and reflect excellent work by field personnel.

Inventory and Classification of Fish Habitat and Streams

We recognized that efforts are being made to clarify the stream protection requirements of the Tongass Timber Reform Act to better and more consistently implement buffers on class I and II streams, as evidenced by the Chatham Area 1993 policy on Reform Act buffers. In some areas, flood-plain habitat, streams, riparian areas, and important wetlands are not well protected because they are misclassified or simply did not show up on inventories used for sale planning and layout. Large woody debris and wetland functions were sometimes not fully recognized in buffer designs during timber-sale layout. Many buffers are designed too narrow to withstand high wind. Some streams, classified as class III and not given a buffer, should have been classified as class II and buffered, based on habitat characteristics for resident fish.

The Tongass Timber Reform Act does not require minimum buffers on class III streams but does require the application of Best Management Practices to them. Class III streams comprise about half of a typical watershed's channel network. These streams are transport channels for the sediment, bedload, and woody debris routed through the streams to downstream fish habitat. We observed that class III streams sometimes are not given buffers or sufficient protective measures to maintain all of their important functions.

Unstable Slopes

The evaluation of landslide hazard and mitigation measures applied to timber harvest and road activities on steep unstable slopes is not always adequate. Slopes with the highest (MMI4) mass-movement rating--based on the Tongass landslide rating system--are considered unsuitable for timber production in the proposed Forest Plan Revision but may be available for timber harvest under the current Plan. The MMI3 category is considered suitable, but these slopes are required to have further site-specific inventory and prescriptions before timber harvest and road activities are planned. Inadequate field checking of the soils data base to verify the hazard associated with the mass-movement classification was apparent from the field review, although our team recognizes that decisions to operate on high-risk soils may have been accepted by Forest leadership in some locations. Tongass procedures for operating on MMI3 areas are generally adequate for minimizing short-term soil displacement and effects of surface erosion. The long-term effects (5-25 years), we believe, are not well addressed by current procedures.

The most serious long-term effect of the current procedures on high mass-movement-hazard soils will be loss of root strength and the resultant increases in mass wasting over the long term. When these steep slopes are clearcut, the roots of the harvested trees slowly decompose and no longer hold the soil in place. Peak loss of root strength, before the strength associated with regrowth of trees returns, is usually at about 10 to 15 years after timber harvest. During periods of intense rainfall, landslides can deliver large amounts of sediment and debris to streams and footslope areas. Negative effects to fish habitat are not always immediate, but accelerated rates of mass wasting are thought to cause long-term, chronic effects (Swanston 1971, Swanson et al. 1987, Swanston and Erhart 1993). Other soil productivity concerns accompany these mass-wasting events, but they are not directly related to fish habitat. Given current procedures, we expect that future timber harvesting and road building will continue to access increasing acreage of MMI3 areas. Complex and unpredictable negative effects will accumulate on downstream fish habitat if wide-spread harvest activities on these MMI3 soils continue over the long term.

Roads

Problems were noted associated with design, construction, maintenance, mitigation, and closure of roads, especially on steep, unstable slopes. Stream crossings are sometimes designed for less than the critical flow, and ditch relief culverts are sometimes not sufficient to maintain the hydrology of steep slopes, hollows, and wetlands. We saw an instance where road construction on highly erosive soils continued through fall storm events, contributing to the sedimentation of streams. Culvert crossings of roads on steep mountain-slope channels was another concern expressed by our Team. These culverts have a tendency to fail and plug with bedload, becoming persistent maintenance problems.

Based on the expert field review and our own observations, road construction problems sometimes needing more timely, consistent mitigation included erosion control at stream crossings, grass seeding on midslope cut-and-fill slopes, and fish passage at class I and II culvert crossings. Also of concern in some locations was the failure to act on decisions to close road segments.

Maintaining roads was a concern identified by some of the field-review experts and our Team. Funds for maintaining the many miles of open roads on the Tongass seem inadequate. Low-use roads typically are not stabilized or "put to bed"--such as by removing culverts, constructing waterbars, outsloping road surfaces, and seeding--after timber harvest.

Timber Harvest Planning

Our Team and the expert reviewers expressed general concerns with the planning process. Problems include not evaluating potential cumulative watershed effects thoroughly (although we recognize that the Stikine Area has had a process for analyzing cumulative effects thresholds in place for a few years), lack of a holistic approach in describing the important watershed functions and processes and how they should be protected, lack of a long-term view over a large watershed landscape, lack of contingency planning for large stochastic events (such as floods and windstorms), and minimal concern for aquatic species other than salmon. All of these examples of planning deficiencies could be due to the pressure to produce timber sale offerings.

Institutional Concerns

Institutional concerns include incomplete updating of the Forest corporate data base; insufficient project-scale inventories for conducting site-specific assessments in sale planning and layout; inadequate input from specialists on geomorphology and fluvial processes; a management climate where the burden of proof is sometimes on fisheries and hydrology specialists to show that activities in riparian areas are detrimental to fluvial processes and fish habitat, rather than other specialists showing that proposed activities in riparian areas will not negatively affect fish habitat and fluvial processes; and emphasis on timber targets rather than on land stewardship.

Giving District personnel the ability to strongly influence harvest unit and road layout during design and implementation was viewed as positive when interdisciplinary teams were given the discretion to design habitat-protection strategies to match on-the-ground conditions. When project decision makers chose to modify recommendations in an effort to meet timber harvest targets or other specific objectives, we often viewed the action as not providing the best or desired fish habitat protection. Best Management Practices and Record of Decision requirements were sometimes not implemented completely because of other commitments of personnel and resources. The Team and the field-review experts expressed strong concern about the current management emphasis on monitoring timber harvest and road-related activities.

QUESTION 2: IS ADDITIONAL PROTECTION NEEDED?

We concluded that the answer to this question is yes. We recommend additional measures to reduce the risk to fish habitat capability on the Tongass National Forest. If these measures are implemented in their entirety, we think additional risks to fish habitat associated with timber management activities will be minimized and the goal of preserving the biological productivity of fish streams on the Tongass will be met, although risk can never be eliminated. Additional protection for fish habitat requires two parallel efforts: the first is an ecosystem approach for evaluating and protecting watershed processes and functions at the landscape scale, and the second is the full implementation of existing Best Management Practices in planning and implementing activities that could affect aquatic ecosystems. Recommendations are also included for addressing research, institutional, and information needs.

Fully implementing an ecosystem approach will require additional measures not currently included in the Tongass Land Management Plan. These measures should be fully examined, disclosed, and included in the Plan revision. Fully implementing Best Management Practices, however, does not require additional analysis; it simply requires us to follow existing direction.

We recommend implementing watershed analysis using the concepts presented in *A Federal Agency Guide for Pilot Watershed Analysis* (1994) as a precursor to timber sales and other management activities that could significantly influence fish habitat. The cornerstone of our approach is an ecosystem analysis applied at the watershed scale.

Although some procedures in watershed analysis are currently implemented as part of timber-sale planning, we believe that the watershed analysis process provides important new information about fish habitat needs and the important factors that influence habitat. Given our concerns about the inconsistent application of riparian management guidelines in class III and smaller streams, the inadequate identification and consideration of high mass-movement soils, and a need for better planning of timber management activities that may influence fish habitat, we believe that this analysis should be a precursor to additional timber management in most watersheds. Watershed analysis places each stream in the context of a continuum where small stream processes provide input into successively larger streams throughout the river system (Vannote et al. 1982). Maintaining this connectivity is important for protecting healthy watersheds and fish habitat (Hicks et al. 1991, Naiman et al. 1992).

We recommend, as part of watershed analysis, that Riparian Management Areas be defined and the area within them managed to fully protect fish habitat in the long term. Key physical and biological processes should be considered when establishing riparian zones on all streams. Because watershed analysis on all Tongass watersheds will not be implemented immediately, we propose the following interim recommendations:

- 1. We recommend that riparian zones adjacent to unconfined alluvial flood plain channels, alluvial fan channels, and glacial outwash channels (Paustian 1992) should not be subject to timber harvest unless they are fully evaluated. The entire floodplain should be considered as the interim Riparian Management Area. In these channel types, riparian zones may extend beyond the minimum width specified under current procedures because the stream is often dissected into a main low-flow channel with several side channels. These side channels are important fish habitat (Hartman and Brown 1987). Ecosystem-scale analysis should consider the whole riparian area, as defined by riparian soils and vegetation. Site specific harvest is only allowable when these riparian areas are fully evaluated and the purpose is consistent with the goal of full riparian protection.

- 2. We recommend using a distance equivalent to the height of a site-potential tree to determine the Riparian Management Area width (assuming it is greater than 100 feet) for confined alluvial channel types of class I and II streams. In no case would Riparian Management Areas be less than 100 feet wide. Again, proposed harvest in these areas should fully protect riparian values. We had similar concerns about confined alluvial channel types that are class I and II streams. In these channels, debris recruitment may come from beyond a fixed 100-foot distance, depending on bank slope, topography, and tree height of the dominant debris-producing trees.

- 3. We recommend minimum 100-foot buffers on each side of class III streams until individual needs are identified during watershed analysis. Class III streams have important water quality values. These streams are also sources for woody debris recruitment and litter, and they deliver nutrient and sediment inputs into larger streams (Hicks et al. 1991, Gregory and Swanson 1991, FEMAT 1993, appendix C.2). These streams are typically high-gradient streams often associated with steep, unstable terrain. Timber management opportunities within the buffers are evaluated case by case, considering mass-movement hazards as well as debris, litter, nutrient, and sediment input.

- 4. We recommend defining a new category, class IV streams for the intermittent or ephemeral colluvial channels and small, perennial spring-fed rill channels that are not dominant sediment-transport streams. Streams that are currently unclassified and class III streams that are misclassified cause some confusion. They should be managed primarily to protect water quality. These streams are typically very small, high-gradient streams draining mountain slopes. They rarely need buffer strips, but often require special provisions for felling, yarding, and determining where to place landings and roads.

We recommend that consistent Forest-wide definitions, inventory standards, and interpretations of mass-movement-hazard areas be developed, and that a full inventory and analysis of high- and very high-hazard soils be conducted. As part of an ecosystem approach to watershed planning, mass-movement hazard should be incorporated into the design of all Riparian Management Areas. Given the results of the comparison between post-Reform Act buffers and watershed analysis recommendations, we believe watershed analysis more accurately blends riparian area concerns with high-hazard geomorphic conditions to identify Riparian Management Areas.

We recommend adopting the following additional management measures where steep slopes, high-hazard soil conditions, or both threaten fish habitat:

- High-hazard soils should not be clearcut or roaded before their mass-movement potential is assessed on-site;
- No slopes greater than 84% should be clearcut; and
- No colluvial hollows or highly dissected mountain slopes greater than 70% should be clearcut.

We recommend including cumulative-effects procedures as part of watershed analysis to display the effects from past management; this analysis would identify where current operating thresholds exist that could influence fish habitat and aquatic resources.

We recommend that a set of objectives for fish habitat management be adopted. They should be measurable and reflect the diversity of fish habitat needs, in addition to serving as key monitoring indicators. We recommend that the current set of interim objectives be improved and expanded to include other measures. We recommend that future inventories be conducted on a watershed-scale that include these objectives as a starting point; regional training will be necessary to ensure consistency in collection methods and interpretation.

We recommend that current guidance expressed in Best Management Practices and other direction be re-examined annually and implemented consistently to protect fish habitat. The following areas need re-emphasis and additional attention.

Design, Layout, and Maintenance of Roads

- Stream crossings should be designed and maintained to ensure the upstream and downstream movement of all life stages of anadromous fish. Similar passage criteria are desirable for resident streams. Site-specific exceptions are to be approved by a line officer in consultation with a fisheries biologist and the Alaska Department of Fish and Game.

- Best Management Practices for mitigating effects of erosion and sedimentation from roads should be implemented consistently.

- Building roads on steep slopes and through flood plains and fens should be avoided. When roads are built in these areas, then stringent implementation of Best Management Practices should be used for timing construction, road standards, season and condition of use, and maintenance.

- A program for annually checking and maintaining culverts should be implemented for the entire Tongass Forest. Where culverts have a high risk of failure during large flow events because of potential debris inputs, contingency designs for road overtopping should be implemented to prevent damage.

- All roads not essential for forest transportation and management needs should be identified and closed. Timely closure of unneeded roads and immediate road drainage and erosion mitigation measures should be vigorously pursued.

- Open-bottom stream-crossing structures or bridges should be used more frequently on low-to-moderate gradient streams where fish passage is required.

Riparian Management Areas

- Windthrown timber in riparian areas should not be subject to timber salvage unless approved by a line officer in consultation with a fisheries biologist or hydrologist and others.

- Streams misclassified during inventory should be correctly classified and riparian management adjusted accordingly during all phases of timber harvest.

- A set of physical criteria should be developed to use with the existing biological criteria for differentiating between class II, III, and IV streams.

- Training in recognizing stream classes should be expanded immediately.

Several monitoring needs that are critical to understanding the long-term effects of forest management on fish habitat were identified during the Team review. We recommend that the current implementation monitoring of Best Management Practices continue, to determine compliance with buffer/riparian area guidelines and road standards. We recommend that studies should be initiated to evaluate the effectiveness of riparian area prescriptions and management practices for protecting fish habitat as expressed by the preliminary fish habitat objectives. A standardized monitoring protocol should be established across the Tongass to facilitate data comparisons.

Significant gaps remain in our understanding of how current management affects fish habitat and aquatic ecosystems in Southeast Alaska. We recommend continuing studies that are designed to help understand the basic life-history requirements of anadromous and resident fish in streams. We also recommend aquatic ecosystem studies that explore the relations between terrestrial and aquatic environments as outlined by the Alaska Working Group on Cooperative Forestry/Fisheries Research. In addition, we recommend additional support of research in the following areas:

- The effects of windthrow on fish habitat in both the short and long terms and how negative effects can be minimized.
- Movement of large woody debris through stream systems.
- Sediment routing studies to determine the risk resulting from mass failures on fish habitat.
- Key measures of habitat and ecosystems to be used as management indicators for aquatic ecosystems.
- Hydrological and biological effects of roads and timber harvest on fens and other wetlands.
- Cumulative effects of management activities on watershed processes and fish habitat.
- Population viability assessment for anadromous fish stocks in Southeast Alaska.
- Adaptive management areas for "learning to manage by managing to learn" (Bormann et al. in press). These areas could be used for testing various stream buffer widths and harvest prescriptions in high mass-wasting hazard areas, for example.

In addition to interim and long-term guidance, several institutional and administrative needs were identified to implement this strategy. We identified these needs as opportunities for improving management of fish and aquatic resources.

Watershed analysis requires a significant commitment of personnel and funds in the short term, but has significant cost-saving potential for the long term. We recommend that a team of watershed analysts including at least a hydrologist/geomorphologist, fisheries biologist, ecologist, geographic information systems analyst, and soil scientist be acquired by each Area to work exclusively to complete watershed analyses for all major watersheds with suitable timber lands on the Tongass. These watershed analysis teams will require new personnel on each of the Areas and the funds to complete the analysis. We recommend that the analyses should be completed by the year 2000. We also recommend that a regional watershed analysis-coordinator position should be established to coordinate information exchange among the Areas, coordinate watershed analysis training for field personnel, and provide information from the analyses to the data base managers to update the corporate data base.

We recommend that the Region expand the role of hydrologists and geologists to include hillslope and fluvial geomorphology. Although some personnel already have these skills, the need for this expertise is critical for evaluating mass-movement hazard and predicting effects from land management on streams and fluvial processes. We recommend continuing the partnership with the Juneau Forestry Sciences Laboratory to calibrate the land form and soils inventory for mass-movement hazard ratings. We recommend geomorphology training for all field personnel working in sale layout, as well as expanded training for hydrologists and geologists in advanced geomorphological concepts. In addition, the Region should acquire geomorphologists for each Area on the Forest.

We recommend timely updating of information from field units so that information is truly "corporate" in the Tongass data base. We consistently identified errors in the Tongass data base during our expert-review exercise. These discrepancies occurred when new information from Districts and

Areas was not incorporated into the Forest data base. More-accurate maps and inventory information will be required if our recommendations for riparian areas, class III streams, and high hazard soil areas are implemented. The tentatively suitable timber-harvest lands need to be analyzed when the land management plan is revised and the data base adjusted accordingly.

Chapter 5. Conclusions

Current procedures for protecting fish habitat have clearly improved the treatment of anadromous fish streams and provided improved protection for valuable stream habitat compared to previous procedures. We concluded, however, that fish habitat is at risk on parts of the Tongass and ultimately stocks of salmon and steelhead over the long term because of deficiencies in current procedures discussed in this report. These deficiencies could have undesirable effects on harvests of salmon and steelhead for commercial, sport, and subsistence uses when oceanic conditions controlling carrying capacity in the Gulf of Alaska decline and freshwater habitat capability becomes more of a controlling factor (Beamish and Bouillon 1993).

Under the proposed Tongass Forest Plan revision, most suitable timber will be harvested within the next 70 years. Given the inconsistent application of Best Management Practices, clearcut harvest on high-hazard soils, inconsistent application of buffer guidelines, and insufficient protection for many headwater streams, we believe that fish habitat capability could be compromised in future decades. We are particularly concerned where timber harvest is in small, island watersheds where small stocks of salmon and steelhead are highly vulnerable to disturbances. Given our lack of knowledge about the viability of these stocks and the status of natural populations, we believe that a more conservative approach to salmon and steelhead habitat protection is necessary.

We made several recommendations for new or revised procedures that should minimize risk to fish habitat, although the risk can never be eliminated. Additional protection for fish habitat requires two parallel efforts: the first, an ecosystem strategy for evaluating and protecting watershed processes and functions at the landscape scale, and the second, full implementation of existing direction, such as Best Management Practices, in planning and implementing activities that could affect aquatic ecosystems.

Interest in protecting the salmon and steelhead resources of the Pacific Northwest region of the United States is national. Concern over declining stocks in California, Idaho, Oregon, and Washington have led to the development of fish habitat protection measures specified under the Pacific Anadromous Fish Strategy (PACFISH). Although these measures have not been applied in Alaska, we believe that a comparison is appropriate. A comparison between current direction, PACFISH procedures, and Team recommendations can be found in table 11.

We believe that the protection of salmon and steelhead habitat on the Tongass National Forest has been substantially improved. Forest personnel are to be commended for their dedication and commitment to protecting this habitat. We believe that implementing the additional measures outlined in this report will increase the likelihood that salmon and steelhead habitat will be protected for the future.

Table 11--Current management procedures, PACFISH, and Fish Habitat Analysis Team: comparison of components

Component	Current management procedures	PACFISH	Team Recommendations
Buffers	The 1986 Aquatic Habitat Management Handbook directs the use of aquatic habitat management units (AHMU's) for managing streamside areas. The units are based on stream class and riparian vegetation, and--when available--land type, soils, and additional stream classification. Objectives and direction for management within the units are provided in the Handbook. A riparian management area is defined in the 1991 proposed revision of the Tongass Land Management Plan. The area includes minimum 100-foot buffers on all streams, 150-foot buffers on some channel types, riparian soils, and very high mass-movement hazard soils adjacent to streams and riparian soils. Management prescriptions (zoning ordinances) within the riparian management area are guided by stream class and channel type, and call for minimum 100-foot no-commercial timber harvest buffers adjacent to all class I streams and those class II streams that flow directly into a class I stream, as required by the 1990 Tongass Timber Reform Act; 100- to 500-foot buffers for lakes; 200-foot no-harvest buffers on most flood plains; and other stream- and channel-type-specific guidance. On class III streams, harvest is allowed on most channel types to the stream edge, but the harvest rate in a watershed is limited. No maximum buffer size is set for any stream. Most current projects have been incorporating the guidelines proposed by the Forest Plan Revision for managing by channel type and stream class, although using them is optional.	Interim widths of riparian habitat conservation areas in the absence of site-specific information are 300 feet for fish-bearing streams and lakes; 150 feet for permanently flowing non-fish-bearing streams, ponds, reservoirs, and wetlands greater than 1 acre; 100 feet in key watersheds and 50 feet in non-key watersheds for seasonally flowing or intermittent streams, wetlands less than 1 acre, and landslides and landslide-prone areas. Some commodity activities are permitted in Conservation Areas if they do not jeopardize habitat quality.	We recommend following the process described in the proposed Tongass Plan revision, with the following changes: the riparian management area expands to include high mass-movement-hazard soils and wetland fens; before completing both watershed and project analyses, adopt no-harvest buffers for the entire flood plain for class I and II streams and no-harvest buffers of one site-potential tree for confined alluvial channels on class I and II streams; and plan for limited harvest buffers of 100 feet for class III streams. We propose a new stream class--class IV: it requires special consideration during timber harvest but typically no coniferous buffer strip. The proposed watershed analysis will recommend site-specific Riparian Management Areas that will modify those described in the Tongass Plan Revision process.
Riparian management objectives	The Aquatic Habitat Management Handbook describes some measurable objectives for: streambank and stream channel stability, temperature sensitivity, fish passage through stream crossings, special road-construction mitigative measures, water quality, and large woody debris. Qualitative objectives for primary and secondary aquatic production are also described.	Interim Riparian Habitat Management Objectives that provide quantifiable definition of desirable habitat conditions are being developed to guide land management decisions until watershed analysis is completed.	We recommend fish habitat objectives for large woody debris, width/depth ratio, and pool frequency based on currently undisturbed conditions. We also recommend further analysis and inventory to establish additional fish habitat objectives.

Component	Current management procedures	PACFISH	Team Recommendations
Key watersheds	Key watersheds are not directly addressed, but values are applied to watersheds through Value Comparison Units. Those with "high" fish ratings might be comparable to PACFISH.	Key watersheds are identified by selecting a subset of watersheds that are important to "at risk" stocks, currently are in "good" condition, or have a high potential for restoration.	No change from current management procedures is recommended.
Wetlands	Presidential Executive Orders 11988 and 11990 require that Federal agencies avoid undertaking or providing assistance for new construction (e.g. roads) in wetlands/flood plains unless the head of the agency finds no practicable alternative and the proposed action includes all practicable measures to minimize harm to wetlands and flood plains. The proposed revised Tongass Land Management Plan states that all management activities under the proposed action will conform to these directives. Specific guidance is given for river, lake, and estuary wetlands.	Implies river, lake, forested, and non-forested wetlands will have special standards and guidelines.	No change from current management procedures is recommended. The value of wetland fens would be emphasized, however, through their incorporation into the Riparian Management Area.
Stream class	Stream classes are mapping units that display specific identified values for aquatic resources. Class I is defined as "streams with anadromous or adfluvial fish habitat, plus reasonably enhanceable habitat upstream of barriers." Class II is defined as "streams with resident fish and generally steep gradient (6-15%)." Class III is defined as streams with no fish populations but with potential water-quality influence on downstream aquatic habitat.	Specific stream classifications are not stated, but stream values are stratified as fish-bearing streams, permanently flowing non-fish streams, and seasonally flowing or intermittent streams.	We recommend adding a set of physical criteria to the determination of class II and III streams. In addition, we recommend adding a class IV stream category.
Upslope stability	Areas of very high mass-movement hazard are removed from the timber base in the 1991 proposed revision to the Tongass Land Management Plan.	Areas of high and very high mass-movement hazard are removed from the timber base.	Areas of very high mass-movement hazard are removed from the timber base. We recommend a reassessment of the rating systems for mass-movement hazard--consistent across the Forest--and no clearcut harvest on high mass-movement hazard areas before this reassessment.

Component	Current management procedures	PACFISH	Team Recommendations
Sensitive stocks	Identification and management of sensitive stocks is directed by Forest Service Manual 2670. The most recent Regional Forester's Sensitive Species List was updated in January 1994. Three fish stocks are on the list. The revised Tongass Plan collected information prioritizing categories of species associated with forests. Forest Service and Alaska Natural Heritage Program are currently cooperating to inventory potentially sensitive areas.	PACFISH recommends a comprehensive inventory of at-risk and unique stocks, and these stocks are currently being studied by the Forest Service and the Alaska Chapter of the American Fisheries Society.	We recommend research on stock identification, assessment, and viability.
Restoration	Restoration is addressed through the revised Tongass Plan project schedules and in the regional watershed-improvement-needs inventory.	Key watersheds receive priority for restoration. Restoration is guided by watershed analysis.	Watershed analysis guides restoration activities.
Watershed analysis	Screening, analysis, or both of cumulative watershed effects is required for projects with significant vegetation-removal or soil-disturbing activities to ensure that the project, considered with other activities, will not increase sediment or water yields beyond acceptable limits. No specific watershed-analysis guidelines have been developed.	Watershed analysis is required before commodity extraction in key watersheds and in all Conservation Areas, and is recommended for other watersheds. It proposes measurable and repeatable indices of habitat quality. A Federal Agency Guide to Pilot Watershed Analysis (1994) has been issued as guidance.	Watershed analysis is recommended before timber harvest and other major land-disturbing activities. This recommendation is similar to PACFISH.
Monitoring	A memorandum of agreement (1992) between the Forest Service and the Alaska Department of Environmental Conservation commits the Forest Service to perform Best Management Practices (BMP) monitoring tasks as described in the Alaska Nonpoint Source Pollution Strategy (1990). Types of BMP monitoring required are implementation, effectiveness, and validation. Implementation monitoring programs were formally established on the Tongass in 1991. In April of 1994, the Regional Forester adopted an effectiveness monitoring strategy for the Tongass. The following issues will receive priority consideration: riparian buffer stability; buffer effectiveness in protecting fish habitat; the effects of roads on fish passage, stream flow, sedimentation, and channel stability; effectiveness of class III stream protection in minimizing erosion and downstream sedimentation; and soil mass movement in relation to roads and harvest units.	Requires watershed-specific monitoring of implementation standards and guidelines, and their effectiveness in achieving the Management Objectives, based on watershed analysis.	The team recommends increased emphasis on monitoring. Most monitoring recommendations fall under the priority items shown in the current management procedures. Additional recommendations include an annual program of monitoring culverts and a monitoring program for fish habitat objectives.

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GLOSSARY [1]

ADAPTIVE MANAGEMENT. A process to improve resource management incrementally as the manager and scientists learn from experience and new scientific findings. (1)

ALEVIN. Larval salmonid that has hatched but has not fully absorbed its yolk sac, and generally has not yet emerged from the spawning gravel. (2)

ALLUVIUM. Material deposited by running water, including the sediments laid down in riverbeds, flood plains, lakes, and estuaries. (2)

ANADROMOUS. Moving from the sea to fresh water for reproduction. (2)

ANCHOR ICE. Ice that extends down to and is attached, or frozen, to the lake [or stream] bottom. (4)

ANGLE OF REPOSE. The maximum slope at which loose or fragmented solid material will stand without sliding. (5)

AQUIFER. A water-bearing stratum of permeable rock, sand, or gravel. (Webster)

BEST MANAGEMENT PRACTICES (BMPs). Methods, measures, or practices selected by an agency to meet its nonpoint source [water pollution] control needs. They include, but are not limited to, structural and nonstructural controls and operation and maintenance procedures. (40 CFR 130.2 (m)).

BUFFER. A strip of vegetation left essentially intact along a stream or lake during and after logging.

CHANNEL. A natural waterway of perceptible extent that periodically or continuously contains moving water. It has a definite bed and banks that serve to confine the water. (6)

CHANNEL TYPE. A classification of stream segments that have fairly consistent physical characteristics. (3)

COLLUVIUM. Rock, detritus, and soil accumulated at the foot of a slope. (Webster).

CUMULATIVE EFFECTS. The effects on the environment that result from the incremental effect of a proposed action when added to other past, present, and reasonably foreseeable future actions regardless of which entity undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time. (40 CFR 1508.7)

DELPHI TECHNIQUE. A process conceived in the mid-1950s to estimate probable effects without the availability of traditional measuring criteria. The process typically uses the anonymous opinion of experts. (7)

EFFECTIVE. The accomplishment of a desired result or fulfillment of a purpose or intent, especially as viewed after the event. (Webster)

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[1] Numbers at the ends of definitions indicate they are quoted or adapted from the sources listed at the end of this glossary.

FEN. A tract of low, wet ground (wetland) containing sedge peat, relatively rich in mineral salts, alkaline in reaction, and characterized by slowly flowing water. Vegetation is generally sedges and grasses, often with low shrubs and sometimes a sparse cover of trees. Sphagnum mosses are absent or of low cover. (8)

GEOGRAPHIC INFORMATION SYSTEM (GIS). A spatial type of information management system that provides for the entry, storage, manipulation, retrieval, and display of data that are geographically referenced and have attributes described. (9)

GEOMORPHOLOGY. The classification, description, nature, origin, and development of present landforms and their relations to underlying structures, and of the history of geologic changes recorded by these surface features. (10)

HABITAT. The place or type of site where a plant or animal naturally or normally lives and grows. (Webster)

HEADWATERS. The source of a stream; the upper slopes of a watershed. (Webster)

HOLLOW. A small valley or basin. (Webster)

INVENTORY. Collection of data for description and analysis of the status, condition, production, or quantity of resources and the geographic location of those resources. (11)

LARGE WOODY DEBRIS (LWD). A term used to describe logs, tree boles, rootwads, and limbs that are in, on, or near a stream channel. Current usage of the term defines LWD as woody material greater than 10.2 centimeters (4 inches) in diameter and equal to or greater than 3.05 meters (10 feet) in length. (6)

MASS WASTING. A general term for the dislodgement and downslope transport of soil and rock material under the direct influence of gravity; includes slow displacement, such as creep and solifluction, and rapid movement, such as rockfall, rockslide, [landslide], and debris flow. (10)

NURSE LOG (nurse debris). Down trees, logs, stumps, and slash from management activities or natural processes that provide a protected or elevated microsite above the saturated zone that is suitable for seed germination and growth.

PACFISH. A management strategy for Pacific salmon and steelhead habitat managed by the Forest Service and Bureau of Land Management in the Pacific Northwest.

PALUSTRINE. Nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands in tidal areas where salinity from ocean-derived salts is below 0.50/00.

PARR. Young salmonid, in the stage between alevin and smolt, that has developed distinctive dark "parr marks" on its sides and is actively feeding in fresh water. (2)

PERCHED CULVERT. A condition with a drop from the elevation of a drain pipe outlet to the elevation of the stream bottom.

POOL. Portion of a stream with reduced current velocity, often with deeper water than surrounding areas and with a smooth surface. (2)

PRACTICE. The actual performance or application [of a principle on-the-ground]; a repeated or customary action; the usual way of doing something. (Webster)

PRESCRIPTION (management prescription). Management practices and intensity selected and scheduled for application on a specific area to attain multiple use and other goals and objectives. (36 CFR 219)

PRISTINE. Belonging to the earliest period or state; uncorrupted by civilization. [Here, without obvious human-caused disturbances.] (Webster)

PROCEDURE. A particular way of accomplishing something; a traditional or established way of doing things; [a direction or guideline]. (Webster)

PROCESS GROUP. Channels formed and maintained by the same or similar fluvial processes; process groups describe the interrelation between runoff, landform relief, geology, and glacial or tidal influences on fluvial erosion and deposition processes. (3)

PRODUCTIVITY. The growth rate of biomass per unit area, usually expressed in terms of weight or energy. (12)

PROGRAM. Sets of activities of projects with specific objectives, defined in terms of specific results and responsibilities for accomplishments. (13)

PROJECT. An organized effort to achieve an objective identified by location, activities, outputs, effects, time, and responsibilities for execution. (13)

REDD. Nest made in gravel, consisting of a depression hydraulically dug by a fish for egg deposition (and then filled) and associated gravel mounds. (2)

RIPARIAN. Pertaining to anything connected with or immediately adjacent to the banks of a stream or other body of water. (6)

RIPARIAN-DEPENDENT RESOURCES. Resources that owe their existence to the riparian area.

RIPARIAN HABITAT. Habitats related to and influenced by surface or subsurface waters, especially the margins of streams, lakes, wetlands, seeps, and ditches. Riparian habitat refers to the transition zone between aquatic and upland habitats.

RIPARIAN MANAGEMENT AREA. Land areas delineated through land management planning [or watershed analysis] to provide for managing riparian resources. Specific standards and guidelines are often associated with riparian management areas. (14)

ROAD CLOSURE (obliteration, decommissioning, "putting to bed"). Restoring the natural runoff characteristics to the site and removing culverts and other road drainage structures so that maintenance is not needed. [The term is also used for administrative closures where the roads are maintained, but not available for public vehicular use.]

RUN. A group of fish migrating in a river (most often on a spawning migration) that may comprise one or many stocks. (2)

SEDIMENT. Fragmented material that originates from weathering of rocks and decomposition of organic material that is transported by, suspended in, and eventually deposited in the stream bed. (6)

SEDIMENT TRANSPORT. The movement of sediment through the stream, from the source area to a point of deposition.

SMOLT. Juvenile salmonid one or more years old that has undergone physiological changes to cope with a marine environment. (2)

STOCK. Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. (2)

STREAM. A natural water course containing flowing water, at least part of the year, supporting a community of plants and animals within the stream channel and the riparian vegetation zone. (6)

STREAM CLASS. A mapping unit that displays an identified value for aquatic resources, such as the presence of anadromous species of fish.

> **STREAM CLASS I.** Streams with anadromous or adfluvial (fish ascending from fresh water lakes to breed in streams) lake and stream habitat. Also included is the habitat upstream from migration barriers known to be reasonable enhancement opportunities for anadromous fish and habitat with high-value resident sport fish populations. (15)
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> **STREAM CLASS II.** Streams with resident fish populations and generally steep (6-15 %) gradient (can also include streams from 0-5 % gradient where no anadromous fish occur). These populations have limited sport fisheries values. These streams are generally upstream of migration barriers or are steep gradient streams with other habitat features that preclude use by anadromous fish. (15)
>
> **STREAM CLASS III.** [All other] streams with no fish populations but with potential to influence water quality on the downstream aquatic habitat. (15)

STREAM CROSSING. The intersection of a road with a stream channel, such as a bridge, pipe arch, culvert, or ford.

SUBSTRATE. The mineral and organic material that forms the bed of the stream. (6)

V-NOTCH RAVINE. A very steep (greater than 15% gradient), deeply incised stream channel usually situated on steep mountainslopes or hillslopes. (3)

WATERSHED (drainage basin; catchment). Total land area draining to any point in a stream as measured on a map, aerial photo, or other horizontal, two-dimensional projection. (2).

WATERSHED CONDITION. A description of the health of a watershed in terms of the factors that affect soil productivity and the ability of the watershed to sustain favorable conditions of flow [such as for fish habitat]. (16)

WINDTHROW. The uprooting and felling of trees by strong gusts of wind; also, patches of trees that have been so felled. (2)

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